Idaho National Engineering Laboratory
FORM INEL-2631#
(Rev. 02-95)

Project File Number	ER-WAG5-54 Rev.2
EDF Serial Number	INEL-95/103
Functional File Number	

ENGINEERING DESIGN FILE

Project/Task   OU 5-05/6-01 RI/FS

Subtask   SL-1 Windblown Soils Contamination

EDF Page   0   of   51 +
Appendices

TITLE: ARA Windblown Area Risk Evaluation

SUMMARY

The summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

The following text, ARA Windblown Area evaluation, was deleted (in Draft form) from Operable Unit (OU) 10-06 Radionuclide-Contaminated Soils Remedial Investigation/Feasibility Study (RI/FS) Report. It is retained here for reference for OU 5-05/6-01 RI/FS decisions and for future evaluation and consideration under the OU 5-12 Comprehensive RI/FS.

The complete draft Section 12 of the OU 10-06 RI/FS Report is included in this EDF with major modifications for clarity, to add the external exposure pathway, and to reference appropriate sections of the OU 10-06 RI/FS Report. Also included are select appendices in support of the ARA Windblown Area evaluation that were deleted from the 10-06 RI/FS Report. These appendices include portions of Appendix A, B, C, E, G, and H of the OU 10-06 RI/FS Report.

Also attached are the meeting minutes of the FFA/CO Project Managers' Meeting, February 28, 1995, in which the decision was made to delete the ARA Windblown Area from the OU 10-06 RI/FS Report (see Highlights, Item 4).

In conclusion, this EDF has been established as a vehicle to document the risk evaluation of the ARA Windblown Area for future consideration and reference. In particular, this document supports a no further action recommendation for the surface soils around the SL-1 Burial Ground. Surface soils surrounding ARA-I&II will be further addressed as site code ARA-23.

Distribution (complete package):   Alan Jines, DOE
Project File

Distribution (summary page only):

Author	Dept.	Reviewed	Date	Approved	Date
Douglas Jorgensen	Buried Waste & Landfills	_J Holden_	9/7/95		
		LMIT Review	Date	LMIT Approval	Date _J Holden_ 9/7/95 for Douglas Jorgensen

12. AUXILIARY REACTOR AREA I & II WINDBLOWN AREA

This report was originally Section 12 of the remedial investigation/feasibility study (RI/FS) report for operable unit (OU) 10-06 (Jessmore 1995) for the Auxiliary Reactor Area (ARA) Windblown Area, and was subsequently deleted from the 10-06 RI/FS and added for further consideration and evaluation to the OU 5-12 Comprehensive RI/FS. It is retained in this engineering design file. The original draft was reviewed and modified in support of evaluations of sites ARA-23 and OU 5-01.

The windblown area under investigation includes all soils outside the ARA I & II perimeter fences and within the outermost EG&G Energy Measurements, Inc. (EMI) 1990 aerial survey isopleths (EMI 1992). The soil in this area is considered potentially contaminated as a result of airborne dispersion of radionuclides from ARA operations. A windblown area at ARA has been identified using the above-stated criteria and is the subject of this document.

This report preserves the results obtained from site characterization activities conducted at ARA to define areas of windblown contamination resulting in radionuclide-contaminated soils. Also presented is a summary of supporting site data, including pertinent historical data. These data have been used to determine the nature and extent of contamination of the radionuclide-contaminated soils, to conduct fate and transport modeling of the radionuclide-contaminated soils, and to prepare the baseline risk assessment that presents the current and future potential risks to human health and the environment posed by these radionuclide-contaminated soils. The ultimate purpose is to define the contamination in the ARA Windblown Area and quantify the risk posed by the contamination to human health and the environment.

12.1 Site Description and History

The ARA is located in the southcentral portion of the INEL, approximately 13 km (8 mi) east of the CFA, and approximately 76 km (47 mi) west of Idaho Falls. The ARA was built for the U.S. Army and was referred to as the Army Reactor Area. The Army used this area to develop a compact reactor for use as a power source at remote bases. The ARA consists of four facility areas: ARA-I, ARA-II, ARA-III, and ARA-IV. These areas are described below. There are two windblown areas, one around ARA-III and one surrounding ARA I & II (see Figure 12-1); ARA-IV has no windblown site. This report focuses on the area associated with ARA I & II.

12.1.1 ARA-I

Auxiliary Reactor Area-I is the farthest south of the four ARA facility areas, and it covers approximately 16 ha (4 acres). The facility was constructed in 1957 to support the Argonne Low-Power Reactor Plant, which was later renamed the Stationary Low-Power Reactor No. 1 (SL-1), then subsequently renamed ARA-II. Auxiliary Reactor Area-I had two buildings: ARA-626, a hot cell building, and ARA-627, formerly a print shop and radiochemistry laboratory.

12.1.2 ARA-II

Auxiliary Reactor Area-II covers approximately 12 ha (3 acres) and is located adjacent to the northwest side of ARA-I. This was originally the site of the SL-1 reactor. Reactor operations began in August 1958. During maintenance operations on January 3, 1961, the reactor was involved in a nuclear excursion and explosion. Cleanup operations were completed 18 months

ARA-III

Fillmore Blvd.

SL-1

A R A - I I

A R A - I

LEGEND

1,100 – 3,500 cps

3,500 – 11,000 cps

11,000 – 35,000 cps

35,000 – 110,000 cps

———— Roads

×   × Fences

The data shown here have been processed
in a manner that suppresses the natural
background. The results are displayed as
relative levels of manmade radionuclide
activity. It is nearly impossible to
convert the relative levels of activity
to a meaningful exposure rate because of
the complex distribution of the nuclides.
The counts per second (cps) scale
represents gross counts across a full
256-channel spectrum in EM!'s aircraft-
based detector system.

0   1000   2000 Feet
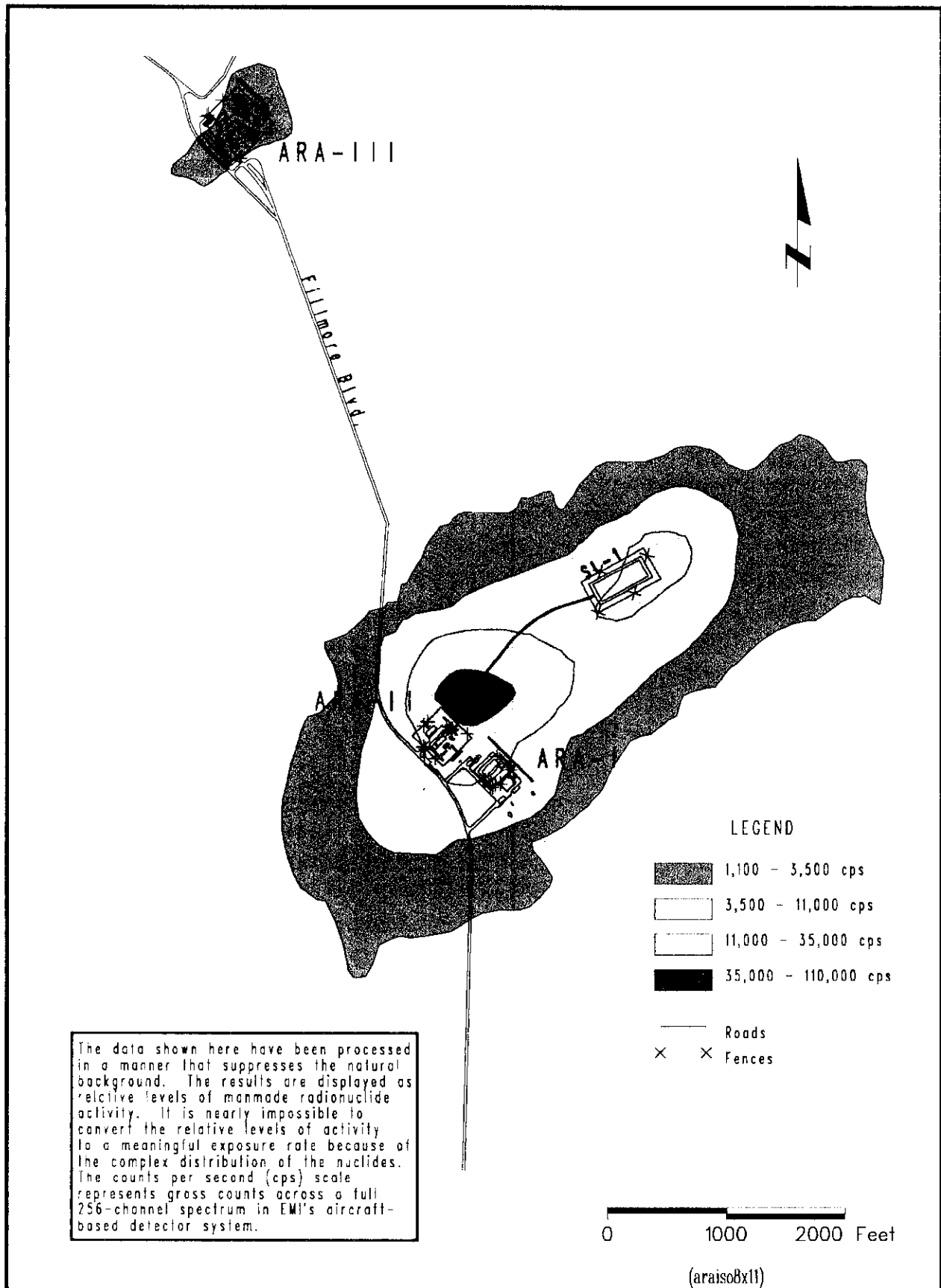
(araiso8x11)

Figure 12-1.   ARA windblown isopleth.

later. Following the accident, the reactor building was disassembled. Debris from the structure, along with contaminated soil from the immediate area, were transported to the newly established SL-1 burial ground located 488 m (1,600 ft) northeast of the SL-1 reactor site. During these cleanup activities, surface soils in the area became contaminated with radionuclides, particularly Cs-137. Subsequent to cleanup and gross decontamination of the facilities, a layer of gravel and asphalt was deposited on top of the soil within the facility boundary, and the area was released for use by other INEL operations. Surface contamination in the area consists principally of particulates. Periodically, particles have been identified on the surface and removed for disposal at the RWMC. Contamination in the surface soils may have been subjected to redistribution by wind over the course of the last three decades.

All activities at the ARA I & II areas were discontinued in 1988. Both facilities are currently undergoing decontamination and dismantlement including the complete removal of most structures and all utilities.

12.1.3 ARA-III

Auxiliary Reactor Area-III is located on approximately 2 ha (5 acres) and is north of the ARA I & II areas. The facility was originally built in the late 1950s to house the Army Gas-Cooled Reactor Experiment. Construction was completed in 1959, and reactor operations began in February 1960. Test work continued until April 1961; the plant was deactivated in 1962.

In 1963, the reactor building and control room were modified for testing of the Mobile Low-Power Plant (ML reactor). The reactor was operated intermittently from April 1964 to September 1965. The Army reactor program was phased out in 1965; since that time, no radioactive research involving reactor operations has been conducted at ARA-III.

Since 1966, the ARA-III facility has been used primarily as a laboratory for testing and evaluating components and instruments used in reactor experiments. Essentially all activities at ARA-III were discontinued in 1984. The facility is currently undergoing D&D and will be returned to its natural state.

12.1.4 ARA-IV

Auxiliary Reactor Area-IV is the largest [8 ha (20 acres)] of the four facilities and the farthest north. The facility was designed to accommodate the ML reactor. The reactor was in operation from 1957 through 1964, when the reactor was moved to ARA-III. From mid-1967 to June 1970, a small Nuclear Effects Reactor was operated at ARA-IV. The area was then closed down until 1975 when it was used temporarily for welding qualification work. In 1984, the facility underwent D&D. Because of its remote location, the facility was used in 1993 to perform explosive-initiated powdered-metal manufacturing experiments.

12.1.5 Previous Soil Investigations

Previous radiological soil investigations have been conducted within the ARA I & II Windblown Area, including aerial radiological surveys, routine soil sampling conducted by RESL, and surface soil surveys. The WAGs 3 and 10 Soils Treatability Study (Gombert et al. 1993) also included portions of the area. A discussion of these investigations follows.

12.1.5.1 1990 Aerial Radiological Survey. The ARA was included in the 1990 EMI aerial radiological survey (EMI 1992) to determine the level of radioactivity deposited on the surrounding soil from ARA operations. Figure 12-1 shows the ionizing radiation isopleth (in counts per second) produced from data collected during the 1990 aerial survey over ARA. The isopleths generally indicate radioactive contamination and were used to identify areas that required more detailed nuclide-specific examination. The outer boundary of the Phase I investigation of radionuclide-contaminated soils at ARA has been established as the outer isopleth resulting from this aerial survey. This is consistent with outer boundaries established for other facilities at the INEL during the OU 10-06 Phase I investigation. For the purposes of the OU 10-06 Phase I investigation, this boundary served to indicate the maximum horizontal extent of soils considered potentially contaminated with radioactivity. The horizontal extent of contaminated soils indicated by the aerial survey may be overestimated. Incident gamma radiation on the detector is likely to be a result of direct radiation whose source is the facility being surveyed and not the surrounding soil. The outer isopleth produced by the EMI aerial survey serves as the outer bound of soil contamination for the OU 10-06 Phase I investigation, but it does not indicate that all or any of the soil within the isopleth is radioactively contaminated.

12.1.5.2 RESL Monitoring. The RESL monitoring program, discussed in Section 1.4.2 of the draft *Remedial Investigation/Feasibility Study Report for Operable Unit 10-06*: INEL-94/003, April 1995 (hereafter referred to as the 10-06 RI/FS report, Jessmore 1995), began collecting soil samples in the vicinity of ARA in the late 1970s. Surface soil samples were collected by RESL in 1977, 1985, and 1991 in the same areas established as potential windblown contaminated areas during the Phase I investigation. Samples were collected from select locations on a circular grid encompassing ARA I & II and extending beyond the SL-1 burial ground. The grid consisted of radial transects centered on ARA-II with sample collection points at regularly spaced intervals.

The RESL typically collected samples from the 0-5- and 5-10-cm (0-2- and 2-4-in.) depths. All samples collected in the vicinity of ARA I & II were analyzed by gamma spectroscopy. Select samples were also analyzed for Sr-90 and by alpha spectrometry for Am-241 and isotopes of uranium and plutonium. Select samples collected in 1977 are archived at the USGS Core Library; all samples collected in 1985 and 1991 are archived. Figure 12-2, a map at the end of this section, depicts the RESL sample collection locations. A summary of the ARA RESL analytical data from surface soil samples is presented in Appendix A. Emphasis has been placed on the RESL data set during collection of historical INEL radionuclide-contaminated soils data because there are over 6,000 data points available from this single source.

As of January 1, 1994, the EG&G Idaho Environmental Monitoring Unit assumed responsibility for onsite sampling and monitoring activities. The responsibility for offsite environmental sampling and monitoring was transferred to the Environmental Science and Research Foundation on April 11, 1994.

12.1.5.3 Surface Soil Surveys. Based on available information, RESL conducted gamma radiation surface soil surveys every 3 to 4 years between 1973 and 1987 in the vicinity of ARA-I, ARA-II, and the SL-1 burial ground. These surveys measured gamma radiation 1 m (3 ft) above the ground using a Ludlum gamma radiation meter. The highest readings in 1984 occurred near ARA-I, where readings ranged from 1,000 to 3,000 μrem/hr (DOE 1984).

Surface soil surveys have also been conducted by the EG&G Idaho Environmental Monitoring Unit on several occasions. Surveys were conducted annually at portions of the SL-1 burial ground completely covering the site over the 3 years between 1987 and 1989. Based on

available information, the results from these surveys indicate a range of readings from 0.05 to 11.0 mrem/hr measured on contact (Wilhelmsen 1987a,b; Wright 1989a,b). Additional surface soil radiological surveys were conducted in 1990, 1991, and 1992 by the same organization. These surveys began in the spring of 1990 and covered the same areas surveyed in the spring of 1987. Available information indicates a range of readings from 0.04 to 4.42 mrem/hr measured on contact (Wright 1990, McBride 1992). A description of these surveys and additional investigations conducted at the SL-1 burial ground is provided in Holdren et al. (1995).

12.1.5.4 WAGs 3 and 10 Radionuclide-Contaminated Soils Treatability Study.

Five samples were collected in the vicinity of ARA under the auspices of this study. One sample each was collected in the following areas: (a) the SL-1 burial ground area (sample location ID ARA-06), (2) the temporary storage area, where soils containing radioactively contaminated particles are placed in boxes awaiting disposal at the RWMC (sample location ID SL-1 Soil Box), (3) an area east of the SL-1 burial ground (sample location ID East of SL-1), (4) an area west of the SL-1 burial ground (sample location ID West of SL-1), and (5) an area southeast of ARA-II, where surface soil contamination has been observed (sample location ID ARA-Outside). As stated in Honeycutt (1994), the postulated mode of deposition for contaminants detected in samples from east and west of SL-1 and ARA-Outside is airborne dispersion. The analytical results from these samples are provided in Table 12-1. Results for the remainder of the samples collected during this study are contained in Gombert et al. (1993).

Table 12-1. Analytical results from the WAGs 3 and 10 radionuclide-contaminated soils treatability study.

Sample location	Gross alpha (pCi/g)	Gross beta (pCi/g)	Cs-137 (pCi/g)
East of SL-1	27.5	1068.8	475.9
West of SL-1	7.9	197.2	224.4
ARA-Outside	31.0	786.5	849.4

12.2 Site Investigations

There were no site-specific investigations conducted within the ARA I & II Windblown Area in support of this investigation for surface features, geological properties, meteorology, surface water and sediment, groundwater, human populations, or ecology.

Contaminant level data collection activities were performed in the vicinity of ARA during the 1993 OU 10-06 Phase I radionuclide-contaminated soils investigation to define areas of windblown contamination resulting from atmospheric dispersion of radionuclides. Phase I sampling in support of the OU 10-06 RI/FS was performed in the vicinity of ARA on August 23, 1993, and included sample collection of surface soils from 0-10 cm (0-4 in.) in depth. In addition, dose equivalent rate measurements, as discussed in Section 12.4.2.1, were collected along the 1993 Phase I ARA transects and at various RESL sampling locations. Additional dose equivalent rate measurements were collected in July 1995 near each of the original RESL soil sample locations. A summary of the analytical data is contained in Appendix A. A summary of the dose equivalent rate data is provided in Section 12.4.2.1. Appendix B contains the full set of dose equivalent rate data collected.

12.2.1 Soil Investigation

The OU 10-06 Phase I field investigation was conducted in the vicinity of ARA I & II in August 1993 to further characterize areas of windblown radionuclide-contaminated soils and to fill existing data gaps. The ARA was included in the Phase I investigation because previous contamination had been detected in the area surrounding ARA by the EMI 1990 aerial survey (EMI 1992) and during monitoring conducted by RESL. A brief discussion of these two surveys is provided in Section 12.1. A discussion on the Phase I soil investigation follows.

12.2.1.1 ARA Phase I Radionuclide-Contaminated Soils Investigation. Eight soil samples were collected at ARA on August 12, 1993, as part of the OU 10-06 Phase I radionuclide-contaminated soils investigation. Samples were collected from the northeast (NE) transect and from three biased areas according to the Phase I Sampling Analysis Plan (Berry et al. 1993). Four samples were collected on the NE transect; two from Biased Area 1 and one each from Biased Areas 2 and 3. All samples were analyzed by gamma spectroscopy. One sample was analyzed by total spectrometric alpha and for Sr-90. Table 12-2 provides the sample number, sample collection date, and transect location of samples collected during the Phase I investigation. All samples were collected on August 23, 1993.

Table 12-2. Sample number and transect location of samples collected during the Phase I investigation at the ARA I & II Windblown Area on August 23, 1993.

Sample number	Transect
5ABS01	Biased Area-1
5ABS01	Biased Area-1
5ABS02	Biased Area-2
5ABS03	Biased Area-3
5ANE01	NE Transect-1
5ANE01	NE Transect-1
5ANE02	NE Transect-2
5ANE03	NE Transect-3

The Phase I ARA sample transect was based on the 1990 aerial EMI radiological survey isopleths (Figure 12-1), predominant wind directions, RESL sample locations, and facility boundaries. The transect began in an area northwest of the facility boundary and terminated at a point approximately 80.5m (50 ft) outside the outer isopleth. The sample outside this isopleth was collected to support the assumption that no contamination occurs outside the isopleth. The outer isopleth is the point at which gamma radiation emitted from facilities or radiologically contaminated soils is indistinguishable from that emanating from background soils. The sample transect was placed in the area within the isopleth where there was little or no existing soil sample data and through the isopleth of highest radiation identified in the 1990 EMI aerial radiological survey.

Sample locations were temporarily staked and flagged before sample collection, and samples were collected as close to these staked locations as possible. All samples collected in the ARA I & II Windblown Area in support of this investigation were surface samples collected from 0-10 cm (0-4 in.) in depth. These samples included subsamples collected from the four corners and center of a 1 x 1-m (3.3 x 3.3-ft) sampling grid. Sample depths were limited to 10 cm (4 in.) in depth for possible comparison to the RESL data set. In addition, previous data collected by RESL confirm the hypothesis that the windblown-deposited radionuclides are restricted to the top few inches of soil.

12.2.1.1.1 Dose Equivalent Rate Measurements—In support of the OU 10-06 Phase I ARA investigation, dose equivalent rate measurements were collected at all Phase I and various RESL sampling locations using a microrem meter. In addition, readings were collected at 15.2m (50-ft) intervals between Phase I sampling locations. The measurements collected are summarized in Section 12.4.2.1. Additional measurements were obtained near all of the original RESL sample locations. These data also appear in Section 12.4.2.1.

12.3 Physical Characteristics

The following subsections describe the physical characteristics of the ARA I & II Windblown Area, which include surface features, meteorology, hydrology, geology, soils, hydrogeology, demography and land use, and ecology.

12.3.1 Surface Features

The study area for radionuclide-contaminated soils at ARA is defined as the areas outside of the facility fences and within the outermost EMI 1990 aerial survey isopleths (Figure 12-1). These areas are located on the flood plain of the Big Lost River. The elevation in the general area (which includes the four ARA areas) ranges from 1,524-1,542 m (5,000-5,060 ft) above mean sea level. Topography in this area is subdued, consisting of low irregular hills separated by shallow valleys and scattered depressions. The land surface slopes gently to the west. The shape of the land surface is essentially that of the upper surface of the uppermost basalt flow. Low areas in basalt have been partially filled by sediments, reducing local relief. Basalt outcrops are common at higher elevations.

12.3.2 Meteorology

The longest and most complete record of meteorological observations exists for the CFA weather station. The ARA and CFA are at approximately the same terrain elevation and have the same exposure to wind, snow cover, and cloud cover. The air temperature, atmospheric humidity, and precipitation data are recorded at CFA (Clawson et al. 1989) and are summarized in Section 1.3.2, 10-06 RI/FS Report, 1995. Air mass characteristics, proximity to moisture sources, angle of solar incidence, and temperature effects caused by latitude differences would be expected to be similar for all locations at the INEL (Bowman et al. 1984), making it possible to extrapolate meteorological data from CFA to ARA.

12.3.2.1 Wind. The predominant wind direction at ARA is from southwest to northeast. Section 1.3.2.3, 10-06 RI/FS Report, 1995, contains general information regarding wind at the INEL.

12.3.3 Hydrology

No perennial streams occur in the ARA. The center of the developed area at ARA is more than 4.8 km (3 mi) from the channel of the Big Lost River at the closest point of approach. This is the only major natural surface water feature near ARA and the closest major drainage to ARA. The Big Lost River is the principal surface water drainage of the INEL.

Water flow in the Big Lost River is intermittent, with flows reaching the Lost River Sinks only during years of high spring runoff and snowmelt from the surrounding mountains. Even during wet years, the river will normally flow only in winter and spring months because water is diverted to spreading areas.

Surface water flow may occur at ARA under certain conditions. Generally, such flow is most likely in the spring, when rare heavy rains combined with warm temperatures, melting snow, and frozen ground result in overland flow and ponding of water in depressions. Alternately, vigorous late-summer thunderstorms may also cause overland flow for brief periods.

12.3.4 Geology

Sparse amounts of geologic data specific to the ARA area are available. Production wells were drilled at ARA-I and ARA-III in 1957 and 1958, respectively, and generalized lithology logs were prepared from the driller's logs. Other wells in the vicinity include the NEP Area 2 well [3.2 km (2 mi) east of ARA-IV] and several wells drilled at the PBF/SPERT areas. The driller's log for well ARA-1 indicates that surficial sediments at that location consist of a layer of clay and small rocks approximately 0.6 m (2 ft) thick. The average depth of surficial sediments in the vicinity of the ARA-I chemical evaporation pond is approximately 0.46 m (1.5 ft), with a maximum depth of 1.1 m (3.5 ft) observed during a 1990 study (Hardy and Stanisich 1990). A similar study undertaken at the sanitary sewage leach field at ARA-III reported that overburden thickness there ranged from 1.2-3 m (4-10 ft) and averaged 1.5-1.8 m (5-6 ft) (Pickett and Spry 1991). Outcrops of basalt are common in the area.

12.3.5 Soils

Surficial materials in the area of ARA consist mainly of fine-grained eolian sediments, interspersed with subordinate alluvial sediments deposited by local runoff. Soils are characterized as sandy loams containing a high percentage of silt and a low percentage of clay (Pickett and Spry 1991).

12.3.6 Hydrogeology

The direction of regional groundwater flow in the SRPA near ARA ranges from south-southwest to south-southeast. This flow direction is based on 1990 water level data from regional wells. Because of the relative scarcity of well data in this region, most of the wells used to determine flow direction are located at a considerable distance from ARA. Although the actual configuration of the water table at ARA may be as complex as that seen at other INEL facilities, this cannot be determined without detailed water level data.

No perched water bodies are known to exist at ARA. Limited quantities of perched water may have existed beneath the ARA waste water disposal ponds when those ponds were in operation, but this is not certain. At other INEL facilities, perched water is generally associated

with laterally continuous, low-permeability sedimentary interbeds. Because of the paucity of stratigraphic information at ARA, it is not known whether such interbeds exist.

12.3.7 Demography and Land Use

Populations potentially affected by activities conducted at ARA include government contractor personnel employed at the INEL, hunters who harvest game living on or near ARA, and residential populations in neighboring communities. Decontamination and dismantlement activities are currently being conducted at ARA I & II.

The BLM has classified the acreage within the INEL as industrial and mixed use (DOE 1991). The INEL is used as a nuclear research, materials, and development facility. The developed area within the INEL is surrounded by a 1,295-km^2 (500-mi^2) buffer zone of grazing land for cattle and sheep (DOE 1991). Grazing areas at the INEL are administered by the BLM. The grazing boundary is approximately 1.6 km (1 mi) south of ARA. During selected years, depredation hunts of game animals, managed by the Idaho Department of Fish and Game, are permitted onsite. Hunters are allowed in a hunting zone that extends 0.8 km (0.5 mi) inside the INEL boundary on portions of the northeast and west borders of the site.

The nearest residential population to ARA is Atomic City, located south of the INEL border on U.S. Highway 26. Other population centers near ARA include Arco, 11 km (7 mi) west of the INEL on U.S. Highway 22/33, and Mud Lake and Terreton on the INEL's northeast border.

In the counties surrounding ARA, approximately 45% of the land is used for agriculture, 45% is open land, and 10% is urban (DOE 1991). Agricultural uses include the production of sheep, cattle, hogs, poultry, and dairy cattle (Bowman et al. 1984). Crops grown include potatoes, sugar beets, wheat, barley, oats, forage, and seed crops. U.S. Department of Energy (1994) indicates that ARA will remain industrial for a minimum of 100 years.

12.3.8 Biota

In general, the flora and fauna at ARA are representative of those found across the INEL. Wildlife species present within the area include various birds, mammals, and reptiles. Flora includes sagebrush, deciduous trees and shrubs, and flora typical of grasslands.

12.4 Nature and Extent of Contamination

The following sections present the results of site characterization activities conducted in support of the 10-06 RI, as well as historical data used to determine the nature and extent of radionuclide-contaminated soils at ARA. The sources of COPCs pertinent to this site are described and the results of the data collected are presented and evaluated to determine the horizontal extent of contamination.

For the purposes of this report, an analyte becomes a COPC if its measured concentration is greater than the 95-95 upper tolerance limit (UTL) for composite samples as calculated in Rood et al. (1995). For the ARA I & II Windblown Area, the COPCs are Cs-137, Am-241, Pu-238, Pu-239/240, and Sr-90. In addition, Co-60, Eu-152, Eu-155, U-233, and U-235 are considered

COPCs because no background values have been established for these radionuclides and they were detected in the area.

12.4.1 Sources

The radionuclide-contaminated soils resulting from atmospheric dispersion in the vicinity of ARA most likely result from a combination of processes and activities that have been performed at ARA since the 1950s. It is well known that radioactive contamination around ARA I & II resulted from the clean up of the SL-1 reactor excursion and explosion in 1961. In addition, during the years of ARA reactor operations, wastewaters containing radiochemical constituents were discharged to various unlined pits, ponds, and ditches. The radionuclides contained in these wastewaters could potentially be a source of the radioactivity detected above background in the area of ARA.

Characterization efforts conducted at ARA I & II confirm the presence of radioactive contamination at several ARA disposal facilities. A summary of several of these characterization efforts follows. In 1990, sediments were sampled from the chemical/evaporation pond (ARA-745) in support of closure under the Consent Order and Compliance Agreement (COCA). Analytical results indicate that surface soil was contaminated with up to 3.71 pCi/g of Cs-137, and the interface between the alluvial materials and the basalt beneath the pond was contaminated with up to 397 pCi/g of Cs-137, 11.4 pCi/g of Cs-134, and 8.14 pCi/g of Co-60 (EG&G Idaho 1990). Field surveys by RCTs indicate that the ARA-I sanitary waste leach field and seepage pit are radioactively contaminated. Other areas that could serve as potential sources of the contamination detected at the ARA I & II Windblown Area are documented in Section 4 and Appendix A of Sehlke and Bickford (1993).

12.4.2 Soils Data

The soil investigation conducted at ARA during OU 10-06 Phase I was performed to determine areas of radionuclide-contaminated soils at ARA as a result of atmospheric dispersion. The resulting data from the Phase I investigation and the nondecayed RESL data are discussed below. The data from both investigations have been used for risk assessment purposes and to determine the nature and extent of contamination in the ARA I & II Windblown Area. Both sets of data indicate that radionuclide-contaminated soils resulting from atmospheric dispersion are present at ARA.

Soil samples collected by RESL at the ARA Windblown Area were collected from 0-5 and 10-cm (0-2 and 2-4-in.) depths whereas soil samples collected by OU 10-06 were collected from 0-10 cm (0-4 in.). As discussed in Rood et al. (1995), concentrations of some radionuclides vary by depth (i.e., Cs-137, Am-241, Pu-238, Pu-239, Pu-240, and Sr-90). Therefore, concentrations of some radionuclides detected in soil samples collected by RESL at 0-5 cm (0-2 in.) may not be comparable to concentrations detected in soil samples collected by OU 10-06 for all radionuclides. To use the analytical results from both RESL and OU 10-06 sampling programs, the analytical results were made comparable by combining and averaging the 0-5 and 5-10 cm (0-2 and 2-4 in.) data from RESL. Soil samples collected by RESL at ARA for all years were used. For those sample locations that did not have analytical results for radionuclides at both depths the assumption was made that the activity from either the 0-5 cm or 5-10-cm (0-2 and 2-4-in.) depth is representative of the entire 0-10-cm (0-4-in.) column. The effects of this assumption are presented in Section 12.6.3. All the analytical results were decayed to September 30, 1994.

The COPCs, as discussed in Section 12.4, are Cs-137, Am-241, Pu-238, Pu-239/240, Sr-90, Co-60, Eu-152, Eu-155, U-233, and U-235. The following discussion summarizes the data for each COPC and compares the maximum concentration detected to the UTL where available.

Cs-137—Cs-137 was detected above background in six Phase I samples. The maximum concentration of Cs-137 detected, occurred at location NE Transect-1 at 4.24 ± 0.35 pCi/g. The next highest concentration occurred at location NE Transect-2 at 3.06 ± 0.23 pCi/g. The remainder of the Cs-137 concentrations range from 0.845 to 0.919 pCi/g. The maximum concentration of Cs-137 reported in the decayed RESL data set occurs at location 0 250' at 262 ± 11 pCi/g. This sample was collected in 1977 from 5-10 cm (2-4 in.) in depth. All of these values are above the UTL reported in Rood et al. (1995) (0.8074 pCi/g).

Am-241—All Am-241 results from the Phase I samples were reported as nondetectable. The maximum concentration of Am-241 reported in the decayed RESL data set occurs at location 22.5 250' at 0.02 ± 0.0025 pCi/g. This sample, collected in 1977 from 0-10 cm (0-4 in.) exceed the UTL reported in Rood et al (1995) (0.011 pCi/g). This is the only data value that exceeds the UTL.

Pu-238—All Pu-238 results from the Phase I samples were reported as nondetectable. The maximum concentration of Pu-238 reported in the decayed RESL data set occurs at location 45 500' at 0.022 ± 0.003 pCi/g. This sample, collected in 1977 from 0-5 cm (0-2 in.). The other data value above UTL occurs at location 0 250' (0.021 ± 0.003 pCi/g). Both values are slightly above the UTL reported in Rood et al. (1995) (0.01 pCi/g).

Pu-239/240—All Pu-239/240 results from the Phase I samples were reported as nondetectable. The maximum concentration of Pu-239/240 reported in the decayed RESL data set occurs at location 0 250' at 0.047 ± 0.004 pCi/g. This sample, collected in 1977 from 0-5 cm (0-2 in.) is slightly above the UTL reported in Rood et al. (1995) (0.0371 pCi/g). This is the only Pu-239/240 data value reported that exceeds the UTL.

Sr-90—All Sr-90 results from the Phase I samples were reported as nondetectable. The maximum concentration of Sr-90 reported in the decayed RESL data set occurs at location 0 500' at 38 ± 2 pCi/g. This sample, collected in 1977 from 0-5 cm (0-2 in.) exceeds the UTL reported in Rood et al. (1995) (0.0.499 pCi/g). Fourteen additional RESL locations indicate Sr-90 concentrations which exceed the UTL.

Co-60-Phase I samples were not analyzed for Co-60. The maximum concentration of Co-60 reported in the decayed RESL data set occurs at location 0 250' at 0.06 ± 0.07 pCi/g. This sample was collected in 1977 from 5-10 cm (0-2 in.) in depth. An examination of the RESL indicates that Co-60 was detected at an 13 additional RESL locations. A UTL has not been determined for this radionuclide.

Eu-152—Phase I samples were not analyzed for Eu-152. Europium-152 was detected at one RESL location decayed to 0.4 ± 0.15 pCi/g (location 56.25 2000'). This sample was collected in 1985 from 0-5 cm (0-2 in.) in depth. A UTL has not been determined for this radionuclide.

Eu-155—Phase I samples were not analyzed for Eu-155. The maximum concentration of Eu-155 reported in the RESL data set occurs at location 112 250' decayed to 0.03 ± 0.04 pCi/g. This sample was collected in 1977 from 5-10 cm (2-4 in.) in depth. This isotope is reported at three other RESL locations. A UTL has not been determined for this radionuclide.

U-233—Phase I samples were not analyzed for U-233. The maximum concentration of U-233 reported in the decayed RESL data set occurs at location 0 1000′ at 1.01 ± 0.04 pCi/g. This sample was collected in 1985 from 0-5 cm (0-2 in.) in depth. Uranium-233 was detected at three other RESL locations. A UTL has not been determined for this radionuclide.

U-235—Phase I samples were not analyzed for U-235. The maximum concentration of U-235 reported in the RESL data set occurs at locations 22.5 1500′ and 67.5 2000′ at 0.053 ± 0.027 pCi/g. These samples were collected in 1985 from 0-5 cm (0-2 in.) in depth. Uranium-235 was detected at four other RESL locations. A UTL has not been determined for this radionuclide.

The minimum, maximum, and mean concentrations for all the isotopes analyzed for the Phase I samples and the locations at which the minimum and maximum concentrations exist are listed in Table 12-3. The nondecayed minimum, maximum, and mean concentrations of the isotopes analyzed for the RESL samples and the locations at which the minimum and maximum concentrations exist are provided in Table 12-4. Appendix A contains the analytical results for all soil samples.

Table 12-3. Radionuclide minimum, maximum, and mean concentrations for soil samples collected during Phase I at the ARA I & II Windblown Area.

| Radionuclide | Concentration (pCi/g) | | Mean | Count[a] |
	Minimum (sample number)	Maximum (sample number)		
Am-241	N/A[b]	N/A	N/A	0/11
Cs-137	0.375 (OBSL0201)	4.24 (5ANE0101[c])	1.12	17/17
Pu-238	N/A	N/A	N/A	0/11
Pu-239	N/A	N/A	N/A	0/11
Sr-90	N/A	N/A	N/A	0/11
U-238	0.8 (OBLS0501)	1.3 (OBLS0101)	0.933	10/11
U-234	0.708 (OBLS0601)	1.25 (OBLS0101)	0.891	11/11

a. Represents the number of true positives versus the number of samples in which the radionuclide was detected/analyzed for.

b. No true positives.

c. Biased sample.

Figure 12-2 shows the Phase I and RESL sample locations and the Cs-137 concentrations detected at those locations. Only the Cs-137 concentrations above the UTL calculated in Rood et al. (1995) are represented on the figure. Sampling locations depicted on the figure with no

Table 12-4. Nondecayed radionuclide maximum, minimum, and mean concentrations for the RESL samples collected at the ARA I & II Windblown Area.

| Radionuclide | Concentration (pCi/g) | | Mean | Count[a] |
	Minimum (sample number, year)	Maximum (sample number, year)		
Am-241	0.003 (270° 500′, 1977)	0.02 (22.5° 250,′ 1977)	0.008	10/16
Co-60	0.034 (135° 250,′ 1977)	0.68 (0° 250,′ 1977)	0.017	13/17
Cs-134	0.046 (90° 500,′ 1977)	0.14 (67° 500,′ 1977)	0.10	3/3
Cs-137	0.064 (337° 2000,′ 1977)	700 (0° 250,′ 1977)	21	187/190
K-40	10.5 (67.5° 500,′ 1985)	20.2 (270° 1000,′ 1991)	16.7	80/80
Pb-212	6.7 (67.5° 500,′ 1985)	1.95 (22.5° 1500,′ 1985)	1.42	63/64
Pb-214	0.78 (67.5° 2000,′ 1985)	1.65 (180° 1500,′ 1985)	1.20	64/64
Pu-238	0.003 (45° 1500,′ 1977)	0.025 (45° 500,′ 1977)	0.011	6/16
Pu-239/240	0.008 (0° 250,′ 1977)	0.047 (0° 250,′ 1977)	0.018	15/15
Sr-90	0.29 (202.5° 3500,′ 1985)	57 (0° 500,′ 1977)	5.8	25/31
U-235	0.043 (67.5° 500,′ 1985)	0.15 (0° 2500,′ 1977)	0.091	4/6
U-238	0.84 (67.5° 500,′ 1985)	1.06 (22.5° 2500,′ 1985)	0.99	4/4
Mn-54	—[b]	0.16 (90° 250,′ 1977)	—	1/1
Sb-125	0.1 (270° 1000,′ 1977)	1 (112° 1000,′ 1977)	0.42	3/3
Be-7	—	130 (45° 2500,′ 1985)	—	1/1
Eu-152	—	0.6 (56.25° 2000,′ 1985)	—	1/1
Eu-155	0.1 (112.5° 250,′ 1977)	0.42 (112° 250,′ 1977)	0.25	6/8
Pa-234m	12 (180° 2500,′ 1985)	14 (112.5° 1500,′ 1985)	13	2/2
Ru-106	—	0.49 (90° 250,′ 1977)	—	1/1
Sc-46	—	0.36 (0° 250,′ 1977)	—	1/1
U-233/234	0.8 (67.5° 500,′ 1985)	1.01 (0° 1000,′ 1985)	0.92	4/4

a. Represents the number of true positives versus the number of sampler in which the radionuclide was detected.

b. Only one true positive detected, reported as the maximum concentration.

corresponding Cs-137 data indicate that this contaminant was either not detected or was below the UTL (i.e., background).

12.4.2.1 Results of the Dose Equivalent Rate Measurements.
Dose equivalent rate measurements were collected in the vicinity of ARA I & II to determine the risk from external exposure from gamma-emitting radionuclides. Dose equivalent rate measurements were collected at all Phase I sampling locations and at 15.2-m (50-ft) intervals between sampling locations. Dose equivalent rate measurements were also collected at 29 of the RESL sampling locations. At the sampling locations measurements were on the 1 scale range from 5 to 220 μrem/hr. A summary of the measurements collected is provided in Table 12-5. The Phase I data in this table represent an average of the measurements collected at the indicated sample location, as appropriate. Additional dose equivalent rate measurements were acquired in July 1995. These data are also included in Table 12-5. A brief discussion on collecting the dose equivalent rate measurements is contained in Section 1.4.4.5.2 of the 10-06 report. A discussion on the screening of the dose rates generated from this survey is presented in Section 12.6. Figure 12-3 displays the dose equivalent measurement rates.

12.4.3 Data Interpretation

The following section presents a brief discussion on the vertical extent of contamination at the ARA I & II Windblown Area. A discussion on the interpretation of the data contained in Section 12.4.2 is also presented and is used to assess the horizontal extent of contamination in this area.

12.4.3.1 Vertical Extent of Contamination.
Because the windblown radionuclide-contaminated surface soil area is thought to result from radionuclides deposited by atmospheric dispersion, it is believed that any radionuclide contamination will be restricted to the upper 10 cm (4 in.) of soil, with the majority of the contamination in the upper 5 cm (2 in.) of soil. This is the basis upon which the OU 10-06 Phase I ARA I & II Windblown investigation was designed. Based on this premise and for possible comparison to the RESL data set, samples were collected from 0-10 cm (0-4 in.) in depth. As discussed in Section 1.4.2, 10-06 RI/FS Report, 1995, RESL conducted a special investigation in 1976 and 1977. The results of this investigation indicate that the majority of the activity in surface soils is confined to the top 10 cm (4 in.) of soil. Subsequent to this investigation, RESL limited sample analysis to those samples collected up to 10 cm (4 in.) in depth.

Based on the results of the RESL investigation, in addition to the suspected method of contaminant deposition, the vertical extent of the radionuclide COPCs resulting from atmospheric dispersion that were detected in the ARA I & II Windblown Area are believed to be restricted to the upper 10 cm (4 in.) of soil. Note that the high concentrations of Cs-137 reported in the RESL data set at the 5-10-cm (2-4-in.) depths in the vicinity of ARA I & II are most likely associated with the SL-1 reactor incident and subsequent cleanup activities and are not attributed to windblown radionuclide deposition.

12.4.2.3.2 Horizontal Extent of Radionuclide COPCs—
An evaluation of the Phase I and nondecayed RESL data sets was performed to assess the horizontal extent of the radionuclide COPCs in the ARA I & II Windblown Area. The results of this evaluation are as follows:

- Concentrations of Cs-137 above background primarily occur at locations adjacent to and in the primary and secondary wind directions from the ARA facility. Several

Dose Equivalent Rates at ARA Windblown Area

LEGEND

—— Paved Roads and Buildings
—·— Fences
—— Depressions
—— Berms
—— Kriging Isopleth Boundary

× RESL Sample Locations
· Phase I Sample Locations (0-4 in. depth)
· Dose Equivalent Sample Locations

Sample Location Name
Dose Equivalent Rate
(micro rem per hour)
(Locations are approximate.)

Filmore Blvd.

SL-1

ARA-II

ARA-I

DRAFT

Date Drawn August 29, 1995

INEL SPATIAL ANALYSIS LABORATORY
APPLYING TECHNOLOGY TO MEET ENVIRONMENTAL NEEDS

(/u2/gisfiles/laney : urem-ara)

Table 12-5. Summary of the dose equivalent rate measurements.

Sample identification			Readings in microrem per hour	
			Scale indicates instrument attenuation	
Sampling group[a]	Sample number	Survey location (nearest facility)	0.1 Scale	1 Scale
Phase I	5ANE01	ARA I	—	13.3
Phase I	5ANE02	ARA I	—	10
Phase I	5ANE03	ARA I	—	10
RESL	0° 250'	ARA	—	70
RESL	0° 500'	ARA	—	70
RESL	0° 1000'	ARA	—	12
RESL	0° 1500'	ARA	—	10
RESL	0° 2000'	ARA	7	10
RESL	0° 2500'	ARA	7	10
RESL	22.5° 250'	ARA	—	220
RESL	22.5° 500'	ARA	—	50
RESL	22.5° 1000'	ARA	—	20
RESL	22.5° 1500'	ARA	—	10
RESL	22.5° 2000'	ARA	8	10
RESL	22.5° 2500'	ARA	8	10
RESL	33.75° 2000'	ARA	—	12
RESL	45° 250'	ARA	—	80
RESL	45° 500'	ARA	—	40
RESL	45° 1000'	ARA	—	20
RESL	45° 1500'	ARA	—	10
RESL	45° 2000'	ARA	—	12
RESL	45° 2500'	ARA	7	5
RESL	56.25° 2000'	ARA	—	20
RESL	67.5° 250'	ARA	—	80
RESL	67.5° 500'	ARA	—	40

12-16

Table 12-5. (continued).

Sample identification			Readings in microrem per hour	
			Scale indicates instrument attenuation	
Sampling group[a]	Sample number	Survey location (nearest facility)	0.1 Scale	1 Scale
RESL	67.5° 1000′	ARA	—	30
RESL	67.5° 1500′	ARA	—	20
RESL	67.5° 2000′	ARA	—	15
RESL	67.5° 2500′	ARA	—	20
RESL	90° 250′	ARA	—	30
RESL	90° 500′	ARA	—	20
RESL	90° 1000′	ARA	—	10
RESL	90° 1500′	ARA	—	5
RESL	90° 2000′	ARA	7	10
RESL	90° 2500′	ARA	7	10
RESL	112.5° 250′	ARA	—	20
RESL	112.5° 500′	ARA	—	20
RESL	112.5° 1000′	ARA	—	10
RESL	112.5° 2000′	ARA	6	5
RESL	112.5° 2500′	ARA	4	5
RESL	135° 250′	ARA	—	15
RESL	135° 500′	ARA	—	10
RESL	135° 1000′	ARA	—	10
RESL	135° 2000′	ARA	5	5
RESL	135° 2500′	ARA	4	5
RESL	157.5° 250′	ARA	—	15
RESL	157.5° 500′	ARA	—	10
RESL	157.5° 1000′	ARA	—	15
RESL	157.5° 1500′	ARA	—	10

Table 12-5. (continued).

Sample identification			Readings in microrem per hour	
			Scale indicates instrument attenuation	
Sampling group[a]	Sample number	Survey location (nearest facility)	0.1 Scale	1 Scale
RESL	157.5° 2000'	ARA	5	5
RESL	157.5° 2500'	ARA	5	5
RESL	180° 250'	ARA	—	20
RESL	180° 500'	ARA	—	20
RESL	180° 1000'	ARA	—	10
RESL	180° 1500'	ARA	—	10
RESL	180° 2000'	ARA	6	5
RESL	180° 2500'	ARA	5	5
RESL	202.5° 250'	ARA	—	15
RESL	202.5° 500'	ARA	—	20
RESL	202.5° 1000'	ARA	—	15
RESL	202.5° 1500'	ARA	—	10
RESL	202.5° 2000'	ARA	7	1010
RESL	202.5° 2500'	ARA	6	10
RESL	202.5° 3370'	ARA	5	5
RESL	225° 250'	ARA	—	15
RESL	225° 500'	ARA	—	25
RESL	225° 1000'	ARA	—	15
RESL	225° 1500'	ARA	—	10
RESL	225° 2000'	ARA	7	10
RESL	225° 2500'	ARA	5	5
RESL	247.5° 250'	ARA	—	10
RESL	247.5° 500'	ARA	—	15
RESL	247.5° 1000'	ARA	—	10

Table 12-5. (continued).

| Sample identification | | | Readings in microrem per hour | |
| | | | Scale indicates instrument attenuation | |
Sampling group[a]	Sample number	Survey location (nearest facility)	0.1 Scale	1 Scale
RESL	247.5° 1500'	ARA	—	10
RESL	247.5° 2000'	ARA	7	10
RESL	247.5° 2500'	ARA	5	5
RESL	270° 250'	ARA	—	15
RESL	270° 500'	ARA	—	10
RESL	270° 1000'	ARA	—	10
RESL	270° 2500'	ARA	8	10
RESL	292.5° 250'	ARA	—	20
RESL	292.5° 500'	ARA	—	20
RESL	292.5° 2000'	ARA	8	10
RESL	292.5° 2500'	ARA	6	5
RESL	315° 250'	ARA	—	20
RESL	315° 500'	ARA	—	15
RESL	315° 1000'	ARA	—	15
RESL	315° 2000'	ARA	7	10
RESL	315° 2500'	ARA	7	10
RESL	337.5° 250'	ARA	—	70
RESL	337.5° 500'	ARA	—	40
RESL	337.5° 1000'	ARA	—	10
RESL	337.5° 2000'	ARA	7	10
RESL	337.5° 2500'	ARA	6	10

a. Phase I samples are averages; all other samples are single readings.

RESL sampling locations outside the outer isopleth show concentrations of Cs-137 thatexceed background. The outer isopleth bounds the horizontal extent of Cs-137 to 5 pCi/g or greater within the isopleth. Concentrations above this limit have not been detected outside the outer isopleth. It is assumed that the large disparity between the maximum concentrations of Cs-137 from the Phase I and RESL data sets is a result of the sample location. The NE Transect-1 sample location is approximately 790 m (2,600 ft) away from ARA-II where contaminant concentrations are expected to be lower than those in the vicinity of the ARA-II, because of the SL-1 reactor incident and explosion in 1961. RESL sample location 0 250' is in the immediate area of ARA-II where soils were disturbed and contamination resulting from the SL-1 incident occurred.

- Concentrations of Pu-238 above background were detected at two locations, both of which are in close proximity to ARA-I, indicating that this radionuclide is not widespread in the ARA Windblown Area and may result from ARA-I operations.

- Concentrations of Pu-239/240 above background were detected at one location. This location is in close proximity to ARA-I, indicating that this radionuclide is not widespread in the ARA Windblown Area and may result from ARA-I operations.

- Concentrations of Sr-90 above background generally occur in close proximity to ARA and in the primary and secondary wind directions. Four RESL sample locations outside the outer isopleth show Sr-90 concentrations above background. At these locations, Sr-90 ranges from 0.45-0.74 pCi/g. The outer isopleth bounds the horizontal extent of Sr-90 to 1 pCi/g or greater within the isopleth.

- Reported concentrations of Co-60 primarily occur in close proximity to the ARA facility. Co-60 has been detected at various RESL sampling locations on all sides of the ARA facility. The majority of the Co-60 concentrations occur within 152 m (500 ft) of the ARA facilities, indicating that Co-60 may be a result of operations performed at the facility. An examination of the RESL data indicates that one sample location outside the outer isopleth (45 5000') had Co-60 detected. At this location, Co-60 was detected at 0.043 ± 0.009 pCi/g.

- Because there is only one available data point for Eu-152, it is not possible to assess the horizontal extent of this radionuclide.

- Concentrations of Eu-155 are not homogeneous throughout the ARA Windblown Area. Reported concentrations of this isotope occur north of the ARA facilities. This isotope is not reported at locations outside the outer isopleth.

- Concentrations of U-233 are not homogeneous throughout the ARA Windblown Area. Reported concentrations of this isotope occur north of the ARA facilities in the primary wind direction. Of the four reported concentrations, three occur within the isopleth at 610 m (2,000 ft) or less from the facilities. An examination of the RESL data indicates that one sample location outside the outer isopleth (22.5 2500') had U-233 detected. At this location, U-233 was detected at 0.94 ± 0.03 pCi/g.

- Concentrations of U-235 are not homogeneous throughout the ARA Windblown Area. Reported concentrations of this isotope occur north of the ARA facilities and in the

primary wind direction. An examination of the RESL data indicates that two sample locations outside the outer isopleth (22.5 2500' and 0.0 2500') had U-235 detected. At these locations, U-235 ranged from 0.53 to 0.15 pCi/g.

An examination of the data indicates that the majority of the contaminants detected above background occur in close proximity to ARA I & II. Contaminant concentrations generally decrease with increasing distance from the facilities. The elevated levels of Cs-137 are most likely the result of the cleanup of the SL-1 reactor excursion and explosion in 1961. During SL-1 reactor cleanup activities soils in the area became contaminated with radionuclides, particularly Cs-137. Because each Phase I sample and the majority of the RESL samples were submitted for Cs-137 analysis and Cs-137 is the primary risk driver, Cs-137 was used as an indicator for determining the horizontal extent of contamination in the ARA Windblown Area. An examination of the most recent nondecayed RESL data collected at sample locations outside the outer isopleth indicate that Cs-137 was detected above background at six locations north, south, east and west of the facility. The isopleth, however, bounds the horizontal extent of Cs-137 contamination within the isopleth to 5 pCi/g or greater.

12.5 Contaminant Fate and Transport

The following subsections address the potential routes of migration for the COPCs at the ARA I & II Windblown Area, their persistence in the environment, and the factors affecting contaminant migration.

12.5.1 Potential Routes of Migration

Air and biota are the two potential migration routes for the COPCs at the ARA I & II Windblown Area to migrate in the environment. Windblown-deposited radionuclides occurring in soils are known to be restricted to the top few inches of soil. When exposed to wind, a potential migration route exists for these contaminants to migrate via atmospheric dispersion.

Biota that inhabit areas of ARA also provide a potential route for contaminants to migrate. Studies performed on migrating animals and insects that inhabit the INEL indicate that these animals can potentially serve as a contaminant migration pathway.

Surface water is not considered a potential route of migration for the COPCs at the ARA I & II Windblown Area because of the lack of surface water features at ARA. The Big Lost River is the only major natural surface water feature in the vicinity of ARA, but the river is more than 4.8 km (3 mi) away and is dry for years at a time. In addition, the river never exits the INEL. During years of high flow, the river infiltrates into the surface in the area of the Big Lost River Sinks, located in the northcentral portion of the INEL.

Groundwater does not serve as a potential route of migration for the contaminants of concern at the ARA I & II Windblown Area because of the shallow depths at which they occur [0-10 cm (0-4 in.)], and the lack of a driving force to the subsurface.

12.5.1.1 Conceptual Site Model. A preliminary conceptual site model was developed as part of the OU 10-06 Scope of Work (EG&G Idaho 1993). Figure A-1 of EG&G Idaho (1993) provides the model for the windblown deposited radionuclide-contaminated soils, which includes soils at the ARA I & II Windblown Area. This preliminary model identifies contaminant release and transport mechanisms, affected media, and potential receptors. The model shows suspension,

intrusion, and radioactive decay as the release mechanisms; air and soil as the transport mechanisms and affected media; and present-day workers, future residents and future recreational users as the potential receptors. A risk characterization based on a modified preliminary conceptual site model was performed for the ARA I & II Windblown Area. Modifications consisted of adding dermal contact as an exposure pathway to the occupational and residential exposure scenarios, ingestion of food crops as an exposure pathway to the residential exposure scenario, and removal of the future recreational exposure scenario. Figure 12-4 presents the conceptual site model.

12.5.2 Contaminant Persistence

The COPCs at the ARA I & II Windblown Area include Am-241, Co-60, Cs-137, Eu-152, Eu-155, Pu-238, Pu-239, Pu-240, Sr-90, U-233, and U-235. The primary process that affects the persistence of these contaminants in the environment is radioactive decay; the longer the decay half-life, the longer the radionuclide will persist in the environment. A discussion of radioactive decay is contained in Section 1.4.4.2.2, 10-06 RI/FS Report, 1995. The decay half-lives for the COPCs are provided in Table 12-6.

Table 12-6. Decay half-lives for COPCs.

Contaminants of potential concern	Decay half-life (yr)
Co-60	5.27E+00
Cs-137	3.01E+01
Eu-152	1.36E+01
Eu-155	4.96E+00
Pu-238	8.77E+01
Pu-239	2.44E+04
Pu-240	6.56E+03
Sr-90	2.9E+01
U-233	1.59E+05
U-235	7.04E+08

The persistence of these contaminants (as indicated by their decay half-lives) in order of most persistent to least persistent is U-235, U-233, Pu-249, Pu-240, Am-241, Pu-238, Cs-137, Sr-90 Eu-152, Co-60, and Eu-155.

Source	Release Mechanism	Transport Media	Exposure Route	Receptor

Contaminated surface soil

Suspension → Air →

Ingestion of fruits and vegetables → Residential

Inhalation → Residential / Occupational

Direct contact → Soil →

Dermal contact → Residential / Occupational

Soil ingestion → Residential / Occupational

Ingestion of fruits and vegetables → Residential

Ionizing radiation → External exposure → Residential / Occupational

RED 0624

Figure 12-4. Modified conceptual site model for the ARA Windblown Areas.

12.5.3 Contaminant Migration

The primary contaminant migration pathway for the ARA I & II Windblown Area, where radioactive contaminants exist in the surface soil, is wind. Biota that inhabit areas of ARA may also play a role in the migration of contaminants in surface soil. Section 1.4.4.4 of the 10-06 RI/FS Report, 1995, provides a detailed discussion of these migration pathways.

The ability of these contaminants to adsorb should also be considered when discussing contaminant migration because adsorption retards the rate of movement. A discussion on adsorption is provided in Section 1.4.4.2.1, 10-06 RI/FS Report, (Jessmore 1995).

12.6 Baseline Risk Assessment

This section presents information and results specific to the baseline risk assessment performed for the ARA Windblown Area. This information includes the presentation of the standard default exposure scenarios, pathways, and time periods, biotic uptake methodology, COPC intake equations, chronic radiation effects, and the methodology for evaluating carcinogenic and noncarcinogenic effects.

12.6.1 Human Health Evaluation

A human health evaluation of the contamination at the ARA Windblown Area is presented in the following sections.

12.6.1.1 Exposure Assessment. This section presents the information needed to quantify the type, magnitude, and duration of exposures to the COPCs at the site.

12.6.1.1.1 Screening Methodology—The radionuclides detected were screened to eliminate radionuclides from further analysis those radionuclides that are below the 95-95 one-sided UTL of the background data and, therefore are indistinguishable from background. Background radionuclide concentrations (i.e., UTL) from Rood et al. (1995) were used. These values were compared with the Phase I and RESL soil samples collected at the ARA Windblown Area to evaluate which radionuclides may be present as a result of past activities (EPA 1989). This section discusses the approach and results of this screening method.

Because there are two separate isopleths at the ARA windblown area, one around ARA I & II and one around ARA-III, each location will be screened individually.

12.6.1.1.1.1 Screening of Radionuclides Detected—Tables 12-7 (ARA I & II) and 12-8 (ARA-III) compare the UTL reported in Rood et al. (1995) and the maximum radionuclide concentrations detected at the ARA Windblown Area.

At ARA I & II, only one soil sample (0.0161 pCi/g) exceeds the background concentration for Am-241 (0.011 pCi/g for the 95-95 UTL and 0.04 pCi/g for the 99-95 UTL). Because this one Am-241 soil concentration is within its analytical uncertainty (0.0025 pCi/g) from background it will not be considered a COPC. Because no radionuclides at the ARA III Windblown Area are above background, this area will not be evaluated in the risk assessment.

Table 12-7. Screening of COPCs at ARA I & II using upper tolerance limits and maximum concentrations detected.

Radionuclide	Upper tolerance limit (pCi/g)	Maximum concentration (pCi/g)	Number of detections above upper tolerance limit/number of samples analyzed	Screened
Am-241	0.011	0.0161	1/15	yes
Co-60	—[a]	0.058	9/14[b]	no
Cs-137	0.82	262	101/138[b]	no
Eu-152	—[a]	0.4	1/1[b]	no
Eu-155	—[a]	0.04	4/6[b]	no
K-40	24	19.6	0/50[b]	yes
Pu-238	0.0049	0.022	3/15	no
Pu-239	0.10	0.055	0/14	yes
Sr-90	0.49	38.0	13/23	no
U-233	—[a]	1.01	4/4	no
U-234	1.44	1.01	0/4	yes
U-235	—[a]	0.15	2/6	no
U-238	1.40	1.06	0/4	yes

a. No background values were determined for these radionuclides.

b. This represents data collected from 0-10 cm (0-4 in.) only. The total number of samples analyzed for gamma-emitting radionuclides represents the number of true positive detections for the OU 10-06 Phase I data and the RESL samples analyzed.

12.6.1.1.1.2 Screening of Dose Equivalent Rates—Dose equivalent rates at the sample locations in the ARA Windblown Area range from 5-220 μrem/hr. As stated in Rood et al. (1995), the UTL for dose equivalent rate is 20 μrem/hr, and any dose equivalent rate above that value will be considered above background. Because several of the dose equivalent rate measurements at the ARA I & II Windblown Area exceed the UTL, the dose equivalent rates are considered to be above background, and the external exposure pathway will be evaluated in the baseline risk assessment.

12.6.1.1.1.3 COPCs—Based on the results of the screening analysis, the COPCs at the ARA I & II Windblown Area are Co-60, Cs-137, Eu-152, Eu-155, Pu-238, Sr-90, U-233, and U-235.

Table 12-8. Screening of COPCs at ARA III using upper tolerance limits and maximum concentrations detected.

Radionuclide	Upper tolerance limit (pCi/g)	Maximum concentration (pCi/g)	Number of detections above upper tolerance limit/number of samples analyzed	Screened
Am-241	0.011	ND[a]	0/1	yes
Cs-137	0.82	0.597	0/3	yes
Pu-238	0.0049	ND[a]	0/1	yes
Pu-239/240	0.10	ND[a]	0/1	yes
Sr-90	0.49	ND[a]	0/1	yes
U-234	1.44	1.11	0/1	yes
U-238	1.40	1.08	0/1	yes

a. ND = Not detected.

12.6.1.1.2 Extent of Contamination—The extent of contamination is determined to provide areal and vertical dimensions of the contamination. The areal extent of contamination will then be used as the area where the receptor(s) are located. The vertical extent of contamination will be used to determine the exposure pathways to be evaluated.

Because the size of the ARA Windblown Area (i.e., the area under the outermost isopleth) is large and the sample locations are spread heterogeneously over this area, the extent of contamination was determined using a data interpolator. Kriging is an optimal method of interpolation because it is a best linear unbiased estimator; therefore, it was selected as the interpolation methodology. Kriging takes into account the spatial correlation (as modeled by the variogram), local sample concentrations, and sample locations to obtain predicted Cs-137 concentrations. In this case, ordinary block or nonpoint kriging was used where the block is the entire ARA Windblown Area. The kriging methodology software package selected was GEO-EAS (EPA 1991a).

The Cs-137 concentrations displayed an adequate structure and were used to define the extent of contamination. Cesium-137 soil concentrations were used because of the large number of sample locations with Cs-137 detected. Typically, the larger the number of sample locations, the more likely a distribution of the data can be observed (e.g., higher concentrations in the middle of a site with lower concentrations farther away from the site). A normal probability plot of the Cs-137 data indicates that they are lognormally distributed. The log-transformed data are used throughout the variogram modeling and kriging because these methods assume normal distributions. The data are back-transformed to units of pCi/g for the final plot of concentrations.

To monitor the concentrations of radioactivity in soil, the RESL sampling program collected data from 1977, 1985, and 1991 at ARA. In some instances, the same sample locations were sampled in more than one year and both radionuclide concentrations were used in the kriging

analysis (i.e., essentially an average value was obtained and used at the sample location). In addition to the RESL data, soil samples collected during OU 10-06 sampling were also used. These include the three transect locations in addition to the 10 background sample locations. The background sample locations were included in the kriging because they are located within the area of the RESL sample locations.

A postplot of the Cs-137 data is presented in Figure 12-5. The Cs-137 postplot indicates a zone of contamination that runs diagonally across the plot. This pattern indicates that the correlation structure depends upon direction.

Spatial dependence, as seen in the Cs-137 sample results, is described by the sample variogram. The variogram measures the variability between concentrations at samples located a given distance apart. Variograms provide a means of quantifying the relationship of samples close together will tend to have more similar values than samples far apart. This relationship is based on the heterogeneity that naturally exists.

The variogram is characterized by four parameters. The first parameter is the model type. The screening uses a Gaussian model. The second parameter is the nugget effect, which is the variation of duplicate samples and is a measure of variation from matrix heterogeneity, analytical, and sampling methods. The nugget effect accounts for the fact that there is not zero variability at zero distances. As the distance increases, the variation increases until a plateau is reached. This plateau of the variogram is called the sill and is the third parameter. Theoretically, the variation will not exceed the total variation in the data. The distance at which the sill is reached is called the range. The range, which is the fourth parameter, is a measure of the distance over which the correlation is present.

The computation of the sample variogram, $\hat{\gamma}_h$, for a given separation distance between sample points, h, is as follows:

$$\hat{\gamma}_h = \frac{1}{2N_h} \sum_h (x_i - x_{i+h})^2 \qquad (12\text{-}1)$$

where the summation is over points located a distance h apart and

$\hat{\gamma}_h$ = sample variogram

N_h = number of pairs of points located a distance h apart

x_i, x_{i+h} = concentrations of sample pair located a distance h apart.

When there is no direction to the spatial dependence, the strength of the correlation between two points depends only on distance. This situation is described using an omni-directional (isotropic) variogram. Initially, this type of variogram was calculated for the ln(Cs-137) concentrations. However, two Cs-137 soil concentrations were quite high (170 and 262 pCi/g) and were removed only for the variogram calculations. Although the postplot indicates some spatial correlation, the directional variogram did not depart much from the omni-directional variogram [i.e., range of influence varied from 152-305 m (500-1,000 ft) using a directional variogram and
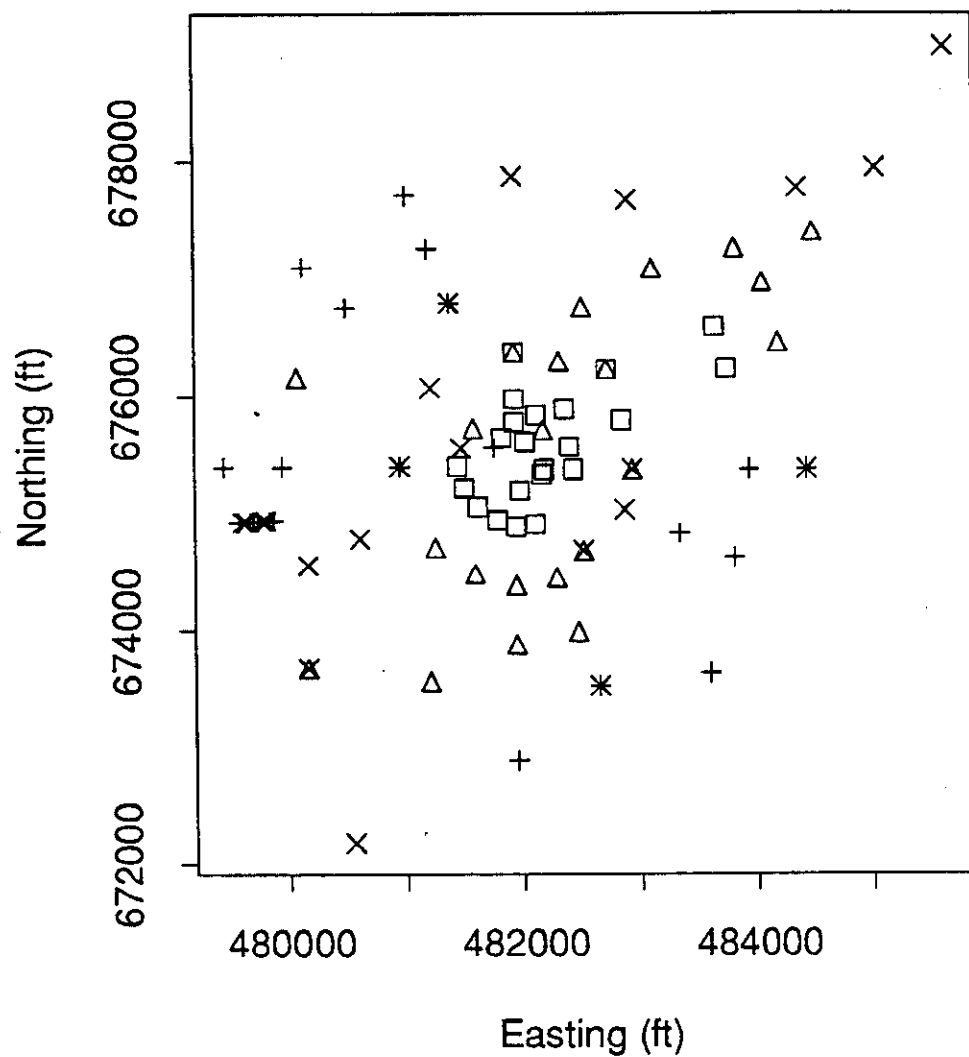
1st Quartile:	$0.26 \leq + \leq 0.65$ pCi/g
2nd Quartile:	$0.65 < \times \leq 1.23$ pCi/g
3rd Quartile:	$1.23 < \triangle \leq 6.13$ pCi/g
4th Quartile:	$6.13 < \square \leq 262.43$ pCi/g

Figure 12-5. Postplot of Cs-137 data at the ARA I & II Windblown Area.

213 m (700 ft) for the omni-directional variogram]. Therefore, an omni-directional Gaussian model was used. The form of the Gaussian model is

$$\hat{\gamma} = n + (S - n)\left[1 - \exp\left(\frac{-3h^2}{r^2}\right)\right] \tag{12-2}$$

where n is the nugget, S is the sill, and r is the range. The nugget is 0.15, the sill is 2.4, and the range is 213 m (700 ft).

The variogram model fit above was used to krige the ln(Cs-137) data. Because the kriging was done on the ln-transformed Cs-137 concentrations, the predicted values from the kriging were back-transformed to the original units (pCi/g). The back-transformed kriging results are shown in Figure 12-6, located at the end of this EDF.

The extent of contamination presented on Figure 12-5 is smaller than the outermost aerial isopleth from the 1990 EMI aerial survey. This is, in part, because of the limitations of the aerial flyover discussed in Section 1.4.1, 10-06 RI/FS Report, 1995, where some of the isopleth is from shine from the facility. In addition, spatial interpolation is a smoothing process where the range of the predicted values will not exceed the range of the observed data. For use in determining the extent of contamination for use in a baseline risk assessment, the focus is on determining an estimate of the average concentration within the contamination zone. Because block kriging results in a smaller standard error of prediction than point kriging, it will result in less uncertainty in the boundaries of the contaminated zone and in the estimated concentration within the zone.

To assess the quality of the results, the standard errors of prediction and the cross-validation of the predicted values with the observed values were calculated. The cross-validation showed the errors (i.e., predicted minus observed values) were roughly normally distributed with a mean of 0.121 and a standard deviation of 1.099 (on the ln-scale). The errors ranged from -3.2 to 4.4 ln(pCi/g). The plot of the observed values against the predicted values showed a linear relationship; therefore, the predicted Cs-137 concentrations are a reasonable fit to the observed data. The correlation between observed and predicted values is 0.75.

Finally, the back-transformed kriging results were compared to an approximate Cs-137 background concentration of 0.8 pCi/g. Standard normal deviates, z, were generated as follows:

$$z = \frac{\hat{P} - 0.8}{SE_{\hat{p}}} \tag{12-3}$$

where $\hat{P}$ is the back-transformed predicted Cs-137 concentrations and $SE_{\hat{p}}$ is the corresponding standard error of prediction. The z-values are plotted in Figure 12-6. When the value exceeds 2.0, it can loosely be inferred that the predicted concentration is significantly greater than background (at $\alpha = 0.05$).

As shown in Figure 12-6, there is an area north-northwest ARA that has the highest predicted Cs-137 concentrations. This area represents the 5 pCi/g isopleth and is 316,000 m^2 (3,376,000 ft^2). It will be used in the baseline risk assessment as the area where the hypothetical receptor is located. The total area at ARA that is significantly different than background is 389,000 m^2 (4,185,000 ft^2). The vertical depth of contamination is assumed to be the sample collection depth [10 cm (4 in.)].

12.6.1.1.3 Exposure Scenarios, Pathways, and Time Periods—The conceptual site model presented in Section 12.5.1.1 is based on the reasonable maximum exposure, which is defined as the highest exposure that is reasonably expected to occur at a site (EPA 1989). A part of this reasonable maximum exposure is that the COPCs must be present at concentrations that pose a potential threat to human health. The term potential means "a reasonable chance of occurrence within the context of the reasonable maximum exposure scenario" (EPA 1989).

Exposure scenarios to be evaluated are selected based on EPA supplemental guidance (EPA 1991b and 1994a). The first of these two guidance documents "Supplemental Guidance for Superfund Risk Assessments in Region 10" (EPA 1991b) recommends that in keeping with the reasonable maximum exposure the current occupational and 30-year residential exposure scenario should be evaluated. According to the second EPA supplemental guidance "Considering Land Use in the CERCLA Remedy Selection Process " (EPA 1994a) remedial decisions are based on land use. At sites where the land use is highly uncertain, it states that "... a range of reasonably likely future land uses should be considered in developing remedial action objectives". Therefore, up to four exposure scenarios will be evaluated in the baseline risk assessments to support these remedial action objectives. At a minimum, the current occupational and 30-year future residential exposure scenario will be evaluated.

In addition, two remaining exposure scenarios will be evaluated. One of these exposure scenarios will be based on information in *Long-Term Land Use Future Scenarios for the Idaho National Engineering Laboratory (Draft)* (DOE 1994). This document indicates that at the ARA Windblown Area industrial land use will occur for the next 100 years. Therefore, this 100-year occupational exposure scenario will be evaluated, but only if it is indicated that risk in the current occupational exposure scenario is greater than the lower limit of the NCP target risk range (10^{-6}). The 100-year residential exposure scenario will also be evaluated to provide an upper bound on the estimated risk in the year 2094. This exposure scenario will only be evaluated if the maximum detected concentration exceeds the preliminary remediation goal (PRG) in the OU 10-06 report based on a risk of 1×10^{-6} in the 30-year residential exposure scenario.

The exposure pathways evaluated for each exposure scenario are presented in the CSM in Section 1.4.5.3. For the occupational exposure scenarios, the incidental ingestion of soil, inhalation of fugitive dust, and external exposure pathways are evaluated. For the future residential exposure scenarios, the incidental ingestion of soil, inhalation of fugitive dust, ingestion of contaminated fruits and vegetables, and external exposure pathways are evaluated.

12.6.1.1.4 Concentration Term—To estimate the intake of a COPC at the site, a concentration term is used. A concentration term is an estimate of the arithmetic average of the concentrations of the COPCs as detected during the sampling program. Because of the uncertainty associated with estimating the true average concentration at a site, the upper 95% UCL of the arithmetic mean is used. This values provides 95% confidence that the true site average will not be underestimated (EPA 1992).

The analytical results used to calculate the concentration term for the soil ingestion, fugitive dust inhalation, and food crop ingestion exposure pathways are presented in Appendix A and Appendix B presents the dose equivalent rates used to calculate the concentration term for the external exposure pathway. Type of distribution for each radionuclide and the dose equivalent

12-30

rates was determined. Six of the COPCs (Co-60, Cs-137, Eu-155, Pu-238, Sr-90, and U-235) and the dose equivalent rates exhibit a lognormal distribution, and the UCLs for these radionuclides were calculated using the following equation (EPA 1992):

$$UCL = e^{(\bar{x} + 0.5\,s^2 + sH/\sqrt{n-1})}$$

where

UCL = upper confidence limit (pCi/g)

$\bar{x}$ = mean of the transformed data (pCi/g)

s = standard deviation of the transformed data (pCi/g)

H = H-statistic (Gilbert 1987)

n = number of samples.

Although the Cs-137 soil concentrations are distributed lognormally, the UCL is not used. Instead, the concentration term was the concentration of maximum predicted Cs-137 concentration based on the kriging results (pCi/g). Using the maximum contour interval is conservative because the UCL (calculated using above equation) was approximately 16.7 pCi/g. The concentration terms for these radionuclides are presented in Table 12-9. In addition, because the UCLs for Eu-155, U-233, and U-235 exceeded the maximum concentration detected, the maximum concentration was used as the concentration term. Because there was only one detection of Eu-152 this concentration was used as the concentration term.

The dose equivalent rates at the ARA I & II Windblown ARA are higher closer to the facility and especially in the northwesterly direction from the facility. Based on this area of higher dose equivalent rate measurements and the higher Cs-137 soil concentrations, the concentration term for the dose equivalent rates is calculated using those measurements taken from within the Cs-137 isopleth on Figure 12-5. This concentration term is 46 μrem/hr whereas the concentration term for the dose equivalent rates based on all measurements is 15 μrem/hr. Therefore, to be conservative, the 46 μrem/hr concentration term is used.

While most radionuclides are more radiotoxic than chemically toxic (i.e., adverse health effects are more likely caused by the energy released during radioactive decay of the radionuclide), uranium is more chemically toxic. Therefore, to evaluate uranium for noncarcinogenic effects, the units of the radioactive uranium soil concentrations (picocuries per gram) were converted to reflect the units of nonradionuclide COPCs in soil (milligrams per kilograms) using the constants 3.7E+10 disintegrations/s/Ci, 6.02E+23 atom/mole, the atomic weight, and half-life of the isotope. The maximum concentration of only U-238 was used as the concentration term because it converts to the highest nonradioactive soil concentration by more than an order of magnitude. This isotope was used even though its soil concentration in units of pCi/g was below background because the chemical toxicity of uranium is from all its isotopes.

Table 12-9. Concentration terms for the COPCs at the ARA I & II Windblown Area.

COPC	Concentration term (pCi/g)
Co-60	0.023[a]
Cs-137	118[b]
Eu-152	0.4[c]
Eu-155	0.04[c]
Pu-238	0.011[a]
Sr-90	5.61[a]
U-233	1.01[c]
U-235	0.15[c]
Uranium	3.15 mg/kg[d]
Dose equivalent rates	46 μrem/hr[a]

a. Ninety-five percent upper confidence limit.

b. Based on the kriging results.

c. Maximum concentration detected.

d. This soil concentration is derived from the maximum soil concentration of U-238.

12.6.1.1.5 Contaminant Transport—This section identifies factors that affect the concentration of the COPCs at a site and describes the processes that transport a COPC to a receptor. Site-specific data from Mitchell (1994) show that the mass loading of particulates in the air around the ARA is approximately 6E-06 g/m^3. Using this information, COPC concentrations in air were calculated and these concentrations are listed in Table 12-10. (See Section 1.4.4, 10-06 RI/FS Report, 1995, for a more detailed discussion of the contaminant transport processes.)

12.6.1.1.6 COPC Intake Equations—Contaminants of potential concern intake equations are presented in Section 1.4.5.1.6, 10-06 RI/FS Report, 1995.

12.6.1.2 Toxicity Assessment. A toxicity assessment was conducted to identify potential adverse effects and toxicity values for COPCs at the ARA I & II Windblown Area. A toxicity value is a numerical expression of a substance dose-response relationship that is used in the risk assessment. Two types of toxicity values are used in a risk assessment for radionuclides. The first is a slope factor for the ingestion and inhalation exposure pathways. The second type of toxicity value is also for the external (i.e., direct) exposure pathway. The Health Effects Assessment Summary Tables (EPA 1994b) provide slope factors for the ingestion and inhalation exposure pathways. For the external exposure pathway, where the concentration term has been defined in microrem per hour, the toxicity value will also in risk of total cancer incidence per microrem. For

Table 12-10. Calculated air concentrations of the COPCs at the ARA I & II Windblown Area.

COPC	Air concentration (pCi/m³)
Co-60	1.4E-07
Cs-137	. 7.9E-04
Eu-152	2.4E-06
Eu-155	2.4E-07
Pu-238	6.5E-08
Sr-90	3.3E-05
U-233	5.9E-06
U-235	6.5E-07
Uranium	1.9E-08 mg/m³

the occupational exposure scenario, the risk of total concern incidency microrem factor is 5.67E-10; for the residential exposure scenario it is 7.61E-10 (EPA 1994c).

12.6.1.2.1 Radionuclides—The radionuclides above background at the ARA I & II Windblown Area are Co-60, Cs-137, Eu-152, Eu-155, Pu-238, Sr-90, U-233, and U-235. The U.S. Environmental Protection Agency classifies all radionuclides as Group A carcinogens (i.e., known human carcinogens) based on emissions of ionizing radiation and on the extensive weight-of-evidence provided by epidemiological studies of radiation-induced cancers in humans (EPA 1994b). As with chemical carcinogens, it is assumed that any dose of radiation can produce adverse effects and that no threshold exists for radiation carcinogenesis. Chronic radiation effects can be produced by ionizing radiation from all radionuclides, and the carcinogenicity from ionizing radiation is related to dose and exposure time. Table 12-11 presents the toxicity values used for these radionuclides. Section 12.6.1.3.2 represents a qualitative characterization of the inhalation hazard from soluble salts of uranium. The toxicity value for the nonradioactive effects of uranium from ingestion is 3E-03 (EPA 1994d).

12.6.1.3 Risk Characterization. Potential risks and hazards associated with the COPCs at the ARA Windblown Area are assessed for hypothetical occupational and residential receptors. Four potential exposure pathways are addressed based on their applicability to each receptor exposure scenario and location:

1. Ingestion of soil

2. Inhalation of fugitive dust

3. Ingestion of food crops (residential scenario only)

4. External (i.e. direct) exposure.

Table 12-11. Slope factors used in the evaluation of carcinogenic effects of radionuclides for the ARA I & II Windblown Area.[a]

COPC	Ingestion slope factor $(pCi)^{-1}$	Inhalation slope factor $(pCi)^{-1}$
Co-60	1.89E-11	6.88E-11
Cs-137[b]	3.16E-11	1.91E-11
Eu-152	5.73E-12	7.91E-11
Eu-155	1.65E-12	9.60E-12
Pu-238	2.95E-10	2.74E-08
Sr-90[c]	5.59E-11	6.93E-11
U-233	4.48E-11	1.41E-08
U-235[d]	4.70E-11	1.30E-08

a. All slope factors are obtained from EPA (1994b).

b. Does not include the effects of its daughter product (i.e., Ba-137m).

c. Includes the effects of its daughter product (i.e., Y-90).

d. Includes the effects of its daughter product (i.e., Th-234).

The dermal contact exposure pathway was not evaluated because either no toxicity information for the COPCs was available or the toxicity information indicated that this exposure pathway is negligible.

The quantitative evaluation of the COPCs for each specific pathway is dependent on the availability of toxicity values to perform the risk calculations for that particular exposure route. Risks are calculated only for those COPCs with established toxicity values. Qualitative evaluations are provided for COPCs for which such toxicity values are not available.

12.6.1.3.1 Quantitative—Noncarcinogenic effects are quantitatively evaluated based on the hazard quotient relative to unity. Carcinogenic risks are quantitatively evaluated and compared to the NCP target risk range of 10^{-6} to 10^{-4}. The methods used in the human health risk assessment follow EPA guidance (EPA 1989). The risk values presented herein are incremental individual lifetime cancer risks because of exposure to the COPCs. Quantitative risk for the soil ingestion and fugitive dust inhalation exposure pathways were determined using the RESRAD computer code. The RESRAD input and output files are presented in Appendix D, Appendix E presents the spreadsheets for the calculation of the food crop ingestion exposure pathway, and Appendix F presents the spreadsheet for the nonradiological hazard quotients for exposure to uranium.

12.6.1.3.1.1 Carcinogenic Effects Methodology—The potential for carcinogenic effects was evaluated by calculating the excess cancer risk from exposure to concentrations of radionuclides based on hypothetical exposure scenarios. For carcinogens, risks represent the incremental probability of an individual developing cancer over a lifetime as a result of exposure to carcinogens.

The methodology for calculating cancer risks through the various exposure routes is to multiply the carcinogenic intake by its toxicity value (EPA 1989):

$$R = I \times TV \tag{12-5}$$

where

R   =   cancer risk, expressed as a unitless probability

I   =   intake [pCi, mg/kg-d, μrem]

TV   =   toxicity value [$(pCi)^{-1}$, $(\mu rem)^{-1}$, $(mg/kg-d)^{-1}$].

Risk values for each exposure pathway evaluated are summed to obtain the total cancer risk for a given radionuclide or metal. The risks for the various radionuclides for each exposure pathway are also summed.

12.6.1.3.1.2 Noncarcinogenic Effects Methodology—The potential noncarcinogenic effects for the oral exposure routes were evaluated by comparing the estimated intake with the RfD. The resulting ratio is the hazard quotient and is defined as

$$HQ = \frac{I}{RfD} \tag{12-6}$$

where

HQ   =   hazard quotient

I   =   total intake (mg/kg-d)

RfD   =   reference dose (mg/kg-d).

If the quotient or hazard index (i.e., the sum of more than one hazard quotient is a hazard index) exceeds one, there may be concern for the potential noncarcinogenic effects because the intake exceeds the RfD. If the hazard index is less than one, the soil concentration of the metal is presumably below the threshold of potential noncarcinogenic effects, and no adverse health effects are expected from exposure to the radionuclide or metal.

12.6.1.3.1.3 Results for the Current Occupational Scenario—The risks and hazard quotients for the exposure pathways evaluated for the current occupational scenario are presented in Table 12-12. The highest risk from all radionuclides across both exposure pathways

Table 12-12. Summary of risks and hazard quotients for the ARA I & II Windblown Area current occupational exposure scenario.[a]

COPC	Soil ingestion		Fugitive dust inhalation		Total[b]	
	Risk	Hazard quotient	Risk	Hazard quotient	Risk	Hazard quotient
Co-60	1E-10	NA[c]	1E-12	NA	1E-10	NA
Cs-137	1E-06	NA	2E-09	NA	1E-06	NA
Eu-152	7E-10	NA.	2E-11	NA	7E-10	NA
Eu-155	2E-11	NA	3E-13	NA	2E-11	NA
Pu-238	1E-09	NA	2E-10	NA	1E-09	NA
Sr-90	1E-07	NA	3E-10	NA	1E-07	NA
U-233	1E-08	NA	1E-08	NA	2E-08	NA
U-235	2E-09	NA	1E-09	NA	3E-09	NA
Uranium[d]	NA	5E-04	NA	NA	NA	5E-04
Total[b]	1E-06	5E-04	2E-08	NA	1E-06	5E-04

a. The risk from the external exposure pathway is 1E-03.

b. Total may not equal the sum of the values in the column because of rounding.

c. Not applicable.

d. Hazard quotients for uranium are based on the maximum soil concentration of U-238.

is 1E-06. The main contributor to this risk is from ingestion of soil contaminated with Cs-137 (1E-06). This is at the lower limit of the NCP-target risk range. The risks from the external exposure pathway (4E-04) are at the upper limit of the NCP-target risk range. The risk from the external exposure pathway is 1E-03.

The hazard quotient for uranium is 5E-04. This is below the target hazard quotient of 1.

12.6.1.3.1.4 Results for the 30-year Residential Scenario—The risks and hazard quotients for the exposure pathways evaluated for the hypothetical future 30-year residential scenario are presented in Table 12-13. The total risk from all radionuclides across all exposure pathways is 7E-05. The main contributors to this risk are Cs-137 [from soil ingestion (2E-06) and food crop ingestion (2E-05)] and from food crop ingestion contaminated with Sr-90 (5E-05). This is slightly above the lower limit of NCP-target risk range. The risks from the external exposure pathway (3E-03) which is above the upper limit of the NCP target risk range. The risk from the external exposure pathway is 9E-03.

Table 12-13. Summary of risks and hazard quotients for the ARA I & II Windblown Area 30-year residential exposure scenario.[a]

COPC	Soil ingestion Risk	Soil ingestion Hazard quotient	Fugitive dust inhalation Risk	Fugitive dust inhalation Hazard quotient	Food crop ingestion Risk	Food crop ingestion Hazard quotient	Total[b] Risk	Total[b] Hazard quotient
Co-60	1E-11	NA[c]	4E-14	NA	2E-11	NA	3E-11	NA
Cs-137	2E-06	NA	1E-09	NA	2E-05	NA	2E-05	NA
Eu-152	6E-10	NA	8E-12	NA	6E-10	NA	1E-09	NA
Eu-155	1E-12	NA	7E-15	NA	1E-12	NA	2E-12	NA
Pu-238	3E-09	NA	3E-10	NA	2E-10	NA	4E-09	NA
Sr-90	2E-07	NA	2E-10	NA	5E-05	NA	5E-05	NA
U-233	6E-08	NA	2E-08	NA	5E-08	NA	1E-07	NA
U-235	9E-09	NA	2E-09	NA	7E-09	NA	2E-08	NA
Uranium[d]	NA	4E-03	NA	NA	NA	1E-03	NA	1E-02
Total[b]	3E-06	4E-03	2E-08	NA	7E-05	1E-03	7E-05	1E-02

a. Risk from the external exposure pathway is 9E-03.

b. Total may not equal the sum of the values in the column because of rounding.

c. Not applicable.

d. Hazard quotients for uranium are based on the maximum soil concentration of U-238.

The hazard quotient for uranium is 1E-02. This value is below the target hazard quotient of one.

12.6.1.3.1.5 *Results for the 100-year Exposure Scenario*—The following section presents the risks from exposure to radionuclides in 100 years. Although the risk from the external exposure pathway in the current occupational and 30-year future residential exposure scenarios are greater than the lower limit of the NCP target risk range, this exposure pathway is not evaluated for this exposure scenario because the maximum measured dose equivalent rate is less than the 100-year residential PRG. The 100-year PRG for dose equivalent rates based on the residential exposure scenario is calculated using the following equation

$$RBC = \frac{Risk}{TV \times ET \times e^{-(0.693/t)Y}} \tag{12-7}$$

where

RBC = risk-based concentration (μrem/hr)

TV = toxicity value (7.61E-10 risk/μrem)

ET = exposure time (24-hr/d)

t = radioactive half-life for Cs-137 (30.2 yr)

Y = time until exposure scenarios begins (100 yr)

Because the radionuclide with the largest number of detections is Cs-137, it is assumed that all the dose equivalent readings also are from Cs-137; therefore the radioactive half-life of Cs-137 was used to decay the dose equivalent rates. Using this equation, the PRG for the 100-year occupational exposure scenarios for the external exposure pathway is 543 μrem/hr. Because the maximum measured dose equivalent rate (i.e., 220 μrem/hr) is less than this PRG, the external exposure pathway will not be evaluated in these 100-year exposure scenarios.

12.5.1.3.1.5.1 *Occupational Exposure Scenario*—The following section presents the risks from exposure to radionuclides in 100 years. This time period was evaluated because the risk from the COPCs at the current occupational exposure scenario are within the NCP target risk range. The occupational scenario was selected for evaluation because (DOE 1994) indicates that the area in the vicinity of the ARA will be developed for industrial uses. Risks from exposure to the radioactive COPCs are presented in Table 12-14.

The total risk for all radionuclides across all exposure pathways is 2E-07. This is below the lower limit of the NCP target risk range.

12.6.1.3.1.5.2 *Residential Exposure Scenario*—The following section presents the risks from exposure to radionuclides for the residential exposure scenario in 100 years. This is being evaluated because the concentrations of Cs-137 and Sr-90 exceed their respective PRGs, which were determined in the FS. Risks from exposure to these two COPCs are presented in Table 12-15. The total risk from exposure to all radionuclides across all pathways is 1E-05 with the main contributors being both the Cs-137 (4E-06) and Sr-90 (8E-06) via the food crop ingestion pathway. This risk is within the NCP target risk range.

Table 12-14. Summary of risks for the ARA I & II Windblown Area 100-year occupational exposure scenario.

COPC	Soil ingestion	Fugitive dust inhalation	Total[a]
Co-60	3E-16	2E-18	3E-16
Cs-137	1E-07	2E-10	1E-07
Eu-152	3E-12	1E-13	4E-12
Eu-155	2E-17	2E-19	2E-17
Pu-238	5E-10	1E-10	6E-10
Sr-90	9E-09	3E-11	9E-09
U-233	1E-08	1E-08	3E-08
U-235	2E-09	1E-09	3E-09
Total[a]	**1E-07**	**2E-08**	**2E-07**

a. Total may not equal the sum of the values in the column because of rounding.

Table 12-15. Summary of risks for the ARA I & II Windblown Area 100-year residential exposure scenario.

COPC	Soil ingestion	Fugitive dust inhalation	Food crop ingestion	Total
Cs-137	5E-07	3E-10	4E-06	4E-06
Sr-90	4E-08	4E-11	8E-06	8E-06
Total	**5E-07**	**3E-10**	**1E-05**	**1E-05**

12.6.1.3.2 Qualitative—Because uranium has a chemical toxicity component to its health effects and no quantitative toxicity values are available for the inhalation pathway, it was evaluated qualitatively for the occupational scenario. The maximum calculated air concentration of soluble uranium compounds at ARA was compared to an OSHA time-weighted average of 5E-02 mg/m^3 (29 CFR 1900.1000). The calculated air concentration for the uranium in soil at the ARA I & II Windblown Area is 2.3E-08 mg/m^3. This value is well below the occupational limit (5E-02 mg/m^3), thereby, indicating that there is no concern for inhalation hazards from the presence of uranium for the occupational exposure scenario.

12.6.2 Ecological Risk Assessment

The ARA I & II Windblown Area was assessed for potential risk to ecological receptors using the screening methodology presented in Van Horn et al. (1995). The soil samples were all taken at 10 cm (4 in.) or less; therefore, the pathway of concern is exposure through the surface soil. Section 1.4.5.4, 10-06 RI/FS Report, 1995, presents the methodology used to evaluate the effects to the ecosystem. Appendix G presents the ecologically based screening levels (EBSL) for each COPC identified.

To provide an indication of risk the concentration terms presented in Table 12-8 were divided by their corresponding EBSLs to yield a screening level quotient (SLQ). The tables in Appendix G show that SLQs do not exceed a target value of 0.1 even if summed across contaminants. An assumption of a concentration factor (CF) value of 1 was used for any radionuclide that did not have a site-specific value determined. There is some evidence that radionuclides may have unusual bioconcentration mechanisms (e.g., animals that are carnivorous or consume certain plants) (IAEA 1992). An example is Cs-137 from Chernobyl fallout studied in Sweden, which reached six times higher concentrations in certain animals (IAEA 1992). At this site, even using a conservative factor of 10 for the CF for any radionuclide, there is still no indication of risk. (This was verified by dividing the minimum EBSL by 10 and using this value to determine the SLQs.) As a result, it is highly unlikely that these COPCs will cause adverse effects to populations of exposed ecological receptors.

12.6.3 Uncertainty

The term uncertainty in a risk assessment describes ways to present key information bearing on the level of confidence in quantitative risk estimates for a site (i.e., no values are known exactly). There are many sources of uncertainty, including incomplete information, disagreement regarding specific values, imprecision in analyses, variability in values used, and modeling assumptions. Also, simplifications and approximations that are sometimes necessary to make an analysis easier or more economical add to the uncertainty in an analysis.

The uncertainty in a risk assessment must be characterized. If enough information is available, sophisticated quantitative estimates of uncertainty can sometimes be assumed. Usually, quantitative statistical uncertainty analysis is not practical or necessary for sites like the ARA I & II Windblown Area (EPA 1989). Therefore, the approach taken in this section for uncertainties associated with the ARA risk assessment is to identify the key sources of uncertainty, indicate what impact they might have on the assessment, and quantify them when practical. The key sources of uncertainty are those variables and assumptions that contribute most to the overall uncertainty.

This section identifies and discusses key sources of uncertainty in the ARA I & II Windblown Area risk assessment, which are grouped according to the step of the risk assessment in which the source is located. The uncertainty source groups used correspond to the six main steps of the risk assessment:

1.   Environmental sampling and analysis

2.   Fate and transport modeling

3.   Exposure assessment

4. Toxicity assessment

5. Risk characterization

6. Ecological risk assessment.

The sources of uncertainty are discussed and summarized in Table 12-16. The table contains a qualitative characterization of the potential magnitude of the effect of each uncertainty factor on the total calculated risk or hazard index. The qualitative characterization is summarized in Table 12-16 in terms of a low, moderate, or high potential magnitude for either underestimating or overestimating the calculated risk. The magnitude levels used here reflect the potential magnitude of the effect of the uncertainty factor on the final calculated risk or hazard index, not the magnitude of the uncertainty itself. This is important in cases where an uncertainty factor is highly uncertain, but the total calculated risk is not sensitive to that particular factor.

Table 12-16. Sources and effects of uncertainties in the ARA I & II Windblown Area risk assessment.

Uncertainty factor	Effect of uncertainty (level of magnitude)	Comment
Environmental Sampling and Analysis		
Quality of data used in kriging analysis	May underestimate or over estimate risk (low)	The precision of the kriging results are limited by the precision and representativeness of the observed data. Rigorous quality assurance procedures maximize the quality of the data and, therefore, minimize the uncertainty in the kriging analysis.
Quality of the spatial correlation model used in the kriging analysis	May underestimate or over estimate risk (moderate)	The kriging results are not grossly affected by the type of model chosen for the correlation structure; however, care must be taken in specifying parameters within the model. Also, selection of the variogram model is a subjective process.
Nature of the underlying spatial continuity of the data used in the kriging analysis	May underestimate or over estimate risk (low)	Areas in which concentrations are relatively homogeneous are subject to less uncertainty than are areas characterized by erratic concentrations. For example, data obtained from areas with randomly-generated hotspots will be subject to a larger degree of uncertainty.
Sufficiency of sampling design for kriging	May underestimate or overestimate risk (low)	The number and location of samples are sufficient for establishing the variogram model and for kriging. Additionally, the cross-validation of the results indicate that the kriging produced reasonable predicted values. Therefore, the areal extent of contamination is estimated fairly accurately.
Possible unidentified contaminants	May underestimate risk (moderate)	The magnitude of this uncertainty can not be determined. Underestimation of human health risk because of insufficient sample data is possible.
Inclusion of 1 negative value reported for soil concentration for Pu-238 and 10 negative values reported for Sr-90 soil concentrations	May slightly underestimate risk (low)	Use of reported negative values reduces average concentration estimates. However, the estimated averages are unbiased and, therefore, more accurate. Use of negative values improves estimates of variance in concentration and produces better characterization of uncertainty.
Screening method used when background data were unavailable	May overestimate risk (low)	Where data were not available to calculate a background value for a contaminant, the contaminant was assumed to be above background and was carried forward to the fate and transport model(s).

Table 12-16. (continued).

Uncertainty factor	Effect of uncertainty (level of magnitude)	Comment
Environmental Sampling and Analysis (continued)		
Comparison of analytical results from 0-5 cm (0-2 in.) or 5-10 cm (2-4 in.) to background values determined for 0-10 cm (0-4 in.)	May underestimate or over estimate risk (low)	Factors such as soil type and the chemical and physical characteristics of the radionuclide affect the depth at which the maximum radionuclide concentration will occur. The depth of this maximum concentration will determine whether the risk is underestimated or overestimated. For example, for radionuclides with maximum concentrations from 0-5 cm (0-2 in.) the 0-10 cm (0-4 in.) background concentrations will be low, thus, resulting in an overestimation of risk. Generally an underestimation of risk occurs for any situation in which the sample depth does not correspond to the maximum concentration depth.
Use of soil sieving procedure on soil samples to separate soil into fine and coarse fractions	Will bias the measured soil radionuclide concentrations towards a higher value and, therefore, overestimate the calculated risk (moderate)	Soil samples were sieved (in order to be consistent with RESL procedures), which separates the soil into a fine fraction (<0.50 mm) and a coarse fraction (>0.50 mm). Analyses were then performed on the fine fraction, which has been found to have a higher activity per unit mass than the coarse fraction at the INEL. A conservative assumption was then made that activity concentration in the coarse fraction is the same as in the fine fraction, thus likely overestimating the calculated risk.
An analysis for alpha-emitting radionuclides was not performed on all of the soil samples taken	May underestimate the calculated risk (moderate)	Limited alpha analyses were performed on soil samples because of historical information that indicates that these radionuclides are not common at INEL locations. Approximately 10% of the samples taken were analyzed for alpha-emitting radionuclides to verify that this was the case (i.e., that gamma-emitting radionuclides are the COPCs). This could result in a lower concentration term for the alpha-emitting radionuclides at the site.
Fate and Transport Modeling		
Inclusion of background levels of contaminants in the concentration terms	May overestimate risk (moderate)	The estimated background values of contaminants were not subtracted from sample results; thus, the concentration terms (and all subsequent steps of the assessment) included background levels.
Use of generic environmental modeling assumptions	May overestimate risk (moderate)	Site-specific data are not available for every parameter. Values were chosen to be conservative for conditions similar to those at ARA; therefore, risks will generally be overestimated.

Table 12-16. (continued).

Uncertainty factor	Effect of uncertainty (level of magnitude)	Comment
Estimation of food transfer factors	May underestimate but probably overestimates risk (moderate)	Site-specific values were not available. Conservative food transfer values were taken from literature; therefore, risks will generally be overestimated.

<div align="center">

Exposure Estimates

</div>

Use of one of three predicted areas of contamination for receptor location	May overestimate risk (moderate)	A hypothetical receptor may randomly access only one or possibly all three of these areas. A receptor accessing more than just the area with highest contamination will effectively dilute the intake and, therefore, lower the risk.
Standard physiological assumptions used (e.g., body weight, inhalation)	May underestimate, but probably overestimates risk (low to moderate)	Actual parameter values for an individual receptor may be different than assumed values. The calculated risk may be underestimated for individuals that differ significantly from the standard assumptions. However, standard values are generally conservative, and actual intake will be similar or lower in the majority of individuals.
Standard exposure conditions used (e.g., exposure times, dietary intakes, drinking water intakes)	Overestimates risk (moderate)	Standard values for these parameters are conservative for most of the population; for example, consumption of locally grown food, exclusive use of local water well, and high fraction of time spent onsite all overestimate exposure.
Future land use assumptions	May overestimate risk (moderate to high)	Scenario uncertainty for this assessment is not quantifiable or avoidable. Every effort has been made to ensure conservative scenarios have been chosen. Actual future land uses may differ, but chosen scenarios are designed to overestimate exposure for most land uses.

<div align="center">

Toxicity Assessment

</div>

Radiation slope factor	May overestimate or underestimate risk (moderate)	Slope factors are based on human data and assumption of linear nonthreshold dose-response. These slope factors are derived from extrapolation from high dose studies to obtain low dose risk estimates.
Lack of dermal absorption toxicity values	May slightly underestimate risk (low)	Dermal absorption of metals is expected to be insignificant when compared to ingestion.

Table 12-16. (continued).

Uncertainty factor	Effect of uncertainty (level of magnitude)	Comment
	Risk Characterization	
Radioactive decay products neglected for parent radionuclides of >1,000 year half-lives	May slightly underestimate risk (low)	Ingrowth of decay products depends on the half-life of parent. For the time scales used in assessment scenarios only small amounts of these products will be produced. This is a very small addition to total risk because risk is dominated by relatively short-lived radionuclides that do not produce decay products.
Use of field survey data to estimate external radiation risk	May underestimate or over-estimate risk (moderate)	This measurement has a high degree of natural variability. However, it is more representative of the dose a receptor may receive through the external exposure pathway than if the soil concentration was used.
	Ecological Risk Assessment	
Estimation of ingestion rates (soil and food)	May overestimate or underestimate risk (moderate)	Intake (ingestion) estimates used for the terrestrial receptors are based on data in the scientific literature when available. Food ingestion rates are calculated by using allometric equations reported in the guidance manual (VanHorn et al. 1995). Soil ingestion parameters from the literature were used whenever possible. Where information did not exist in the literature on soil ingestion rates for terrestrial biota, soil ingestion rates are assumed to be 2% of the food ingestion rate for all burrowing mammals and birds who consume whole terrestrial prey and 1% for all other receptors of concern.
Estimation of bioaccumulation factors	May overestimate or underestimate the true EBSL, and the magnitude of error cannot be quantified (high)	Very few bioaccumulation factors, CFs, or plant uptake factors are available in the scientific literature because they must be both contaminant- and receptor-specific. In the absence of a site-specific CF, a value of 1.0 is assumed for all contaminants and receptors.
Use of adjustment factors in exposure assessment	May overestimate (high) or underestimate risk (low)	To compensate for potential uncertainties in the exposure assessment, various adjustment factors are incorporated that are designed to err on the side of conservatism. Uncertainties inherent in the exposure assessment are associated with selecting receptors of concern and estimating the site use by receptors of concern. Additional uncertainties are associated with depicting site characteristics, determining the nature and extent of contamination, and deriving toxicity reference values. All these factors are likely to influence risk estimates.

12.7 Summary

12.7.1 Nature and Extent

The area of potential windblown radionuclide-contaminated soil at ARA was originally based on the ionizing radiation isopleths produced by the EMI 1990 aerial survey (Figure 12-1). According to EMI, the 1990 isopleths in the vicinity of ARA resulted from gamma-rays emitted by Cs-137 in the northeastern and southwestern portion of the ARA Windblown Area. Cesium-137 was detected at elevated levels in OU 10-06 Phase I and RESL samples collected in these areas, indicating that the EMI isopleth is a result of gamma-rays emitted by Cs-137. The windblown soils identified at ARA have become part of a new site (ARA-23). Any potential remediation will be addressed under the OU 5-12 Comprehensive RI/FS.

To determine the nature and extent of radionuclide-contaminated soils in the ARA I & II Windblown Area, samples were collected during the OU 10-06 Phase I investigation. The vertical extent of radionuclide-contaminated soils is believed to be restricted to the upper 10 cm (4 in.) of soil. An evaluation of the Phase I and RESL data sets was performed to determine the horizontal extent of radionuclide-contaminated soils. The majority of the elevated Cs-137 concentrations observed occur in the vicinity of ARA-I and ARA-II. This is most likely a result of the SL-1 reactor excursion and explosion in 1961. Elevated Cs-137 concentrations also occur in the primary wind direction. At ARA, contaminant concentrations generally decrease with increasing distance from the facilities. These observations are indicative of windblown contamination. The isopleth generated using the Phase I and RESL data sets bounds the horizontal extent of Cs-137 contamination to 5 pCi/g or greater within the isopleth, as depicted in Figure 12-2.

12.7.2 Fate and Transport

Contaminants of concern for the ARA Windblown Area are limited to radionuclides originating from activities associated with ARA operations. Half-lives govern the persistence of radionuclides in the environment. The activity of any radionuclide is reduced to less than 1% after seven half-lives. The radionuclides of concern include Cs-137 and Sr-90, which have half-lives of 30.17 and 29 years, respectively.

The primary route of potential contaminant migration at the ARA Windblown Area is atmospheric dispersion. Surface water was not considered a potential contaminant migration route because of the lack of surface water features at or near ARA. Groundwater was not considered a potential contaminant migration route because of the shallow depths at which the contaminants occur, large depth to groundwater, and the lack of a driving force to the subsurface.

12.7.3 Baseline Risk Assessment

The baseline risk assessment evaluated the potential adverse health effects to current workers and hypothetical future residents. The COPCs evaluated in this baseline risk assessment are Cs-137, Pu-238, Sr-90, and dose equivalent rates which were detected above background concentrations in surface soils, and Co-60, Eu-152, Eu-155, U-233, U-235, and uranium because no background values were available. All exposure pathways identified on the site CSM for windblown sites except dermal exposure were evaluated. The dermal exposure route was not

evaluated because of a lack of toxicity information. In addition, because the maximum concentration detected for Sr-90 and Cs-137 exceeded the PRGs in the FS, the 100-year occupational and residential exposure scenarios were also evaluated.

Results from the human health risk assessment indicates that Cs-137 for the current occupational scenario is at the lower limit of the NCP target risk range (1E-06) for the soil ingestion and fugitive dust inhalation exposure pathway and it is 1E-03 for the external exposure pathway. For the 30-year residential exposure scenario, the risk is 5E-05 from food crop ingestion of Sr-90 and 2E-05 for food crop ingestion of Cs-137, which pose risks within the NCP target risk range of 10^{-6} to 10^{-4}. Risk from the external exposure pathway is 9E-03. The total risk for the 100-year occupational scenario is 2E-07, and the total risk for the 100-year residential exposure scenario is 1E-05 due to food crop ingestion of Cs-137 (4E-06) and Sr-90 (8E-06). The hazard quotient for uranium is below the target hazard quotient for both the occupational and residential exposure scenarios.

An ecological risk assessment was performed to assess the potential risk to ecological receptors in the ARA I & II Windblown Area. The results of this evaluation indicate that it is unlikely that the COPCs at the ARA I & II Windblown Area will cause adverse effects to populations of exposed ecological receptors.

ARA Windblown Area

ARA-III

Fillmore Blvd.

SL-1

ARA-II

ARA-I

LEGEND

——— Paved Roads

- - -→ Fences

——— Outermost Isopleth Boundary (EMI 1992)

× RESL Sample Locations

• Phase I Sample Locations (0-4 in. depth)

Sample Location Name
Concentration (pCi/g)
Cs-137

(Depicted concentrations are above
INEL background values calculated
in Rood et al, 1994.)

Date Drawn September 07, 1995

0   500   1000   1500   2000   2500 Feet

INEL SPATIAL ANALYSIS LABORATORY
APPLYING TECHNOLOGY TO MEET ENVIRONMENTAL NEEDS

/u2/gisfiles/laney : laneyara4 (REV. 1)
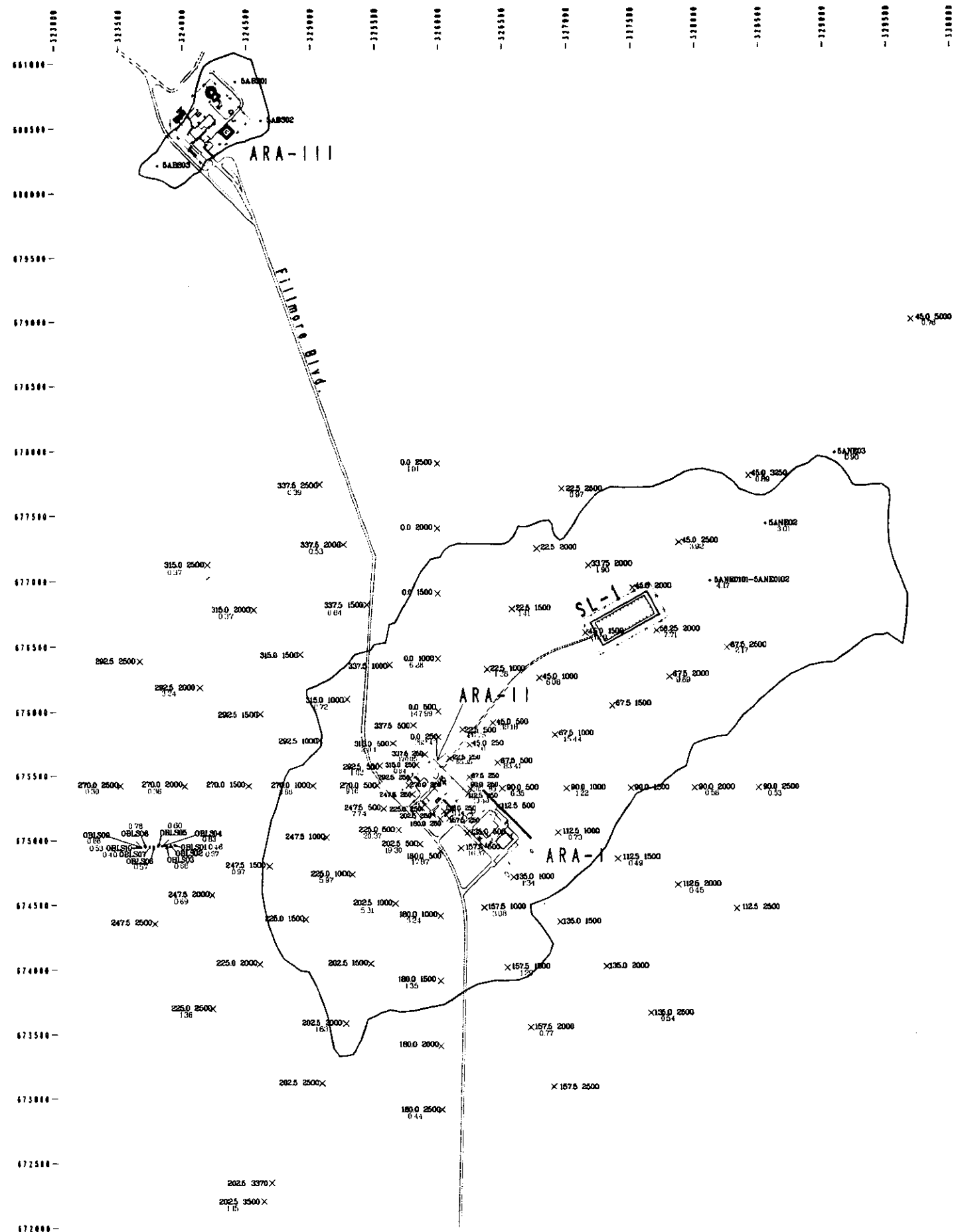
ARA Windblown Area Cs-137 Kriging Results

LEGEND

—— Paved Roads and Parking

·—·— Fences

—— Outermost Isopleth Boundary (EMI 1992)

—— Kriging Isopleth

—— Kriging Z-Value Boundary (Cs-137 Concentrations Greater Than This Value are Significantly Greater Than Background)

× RESL Sample Locations (sample depths are listed in Appendix A)

· Phase I Sample Locations (0-4 in. depth)

1.23 Cs-137 Concentration (pCi/g) Decayed to September 30, 1994

NOTE: These sample locations shown on this map are the only locations used to develop the kriging results.

Kriging contours are at 5 pCi/g intervals.

To ARA-III

Fillmore Blvd.

ARA-II

ARA-I

SL-1

Date Drawn September 07, 1995

INEL SPATIAL ANALYSIS LABORATORY
APPLYING TECHNOLOGY TO MEET ENVIRONMENTAL NEEDS

/u2/gisfiles/laney : ara4krig
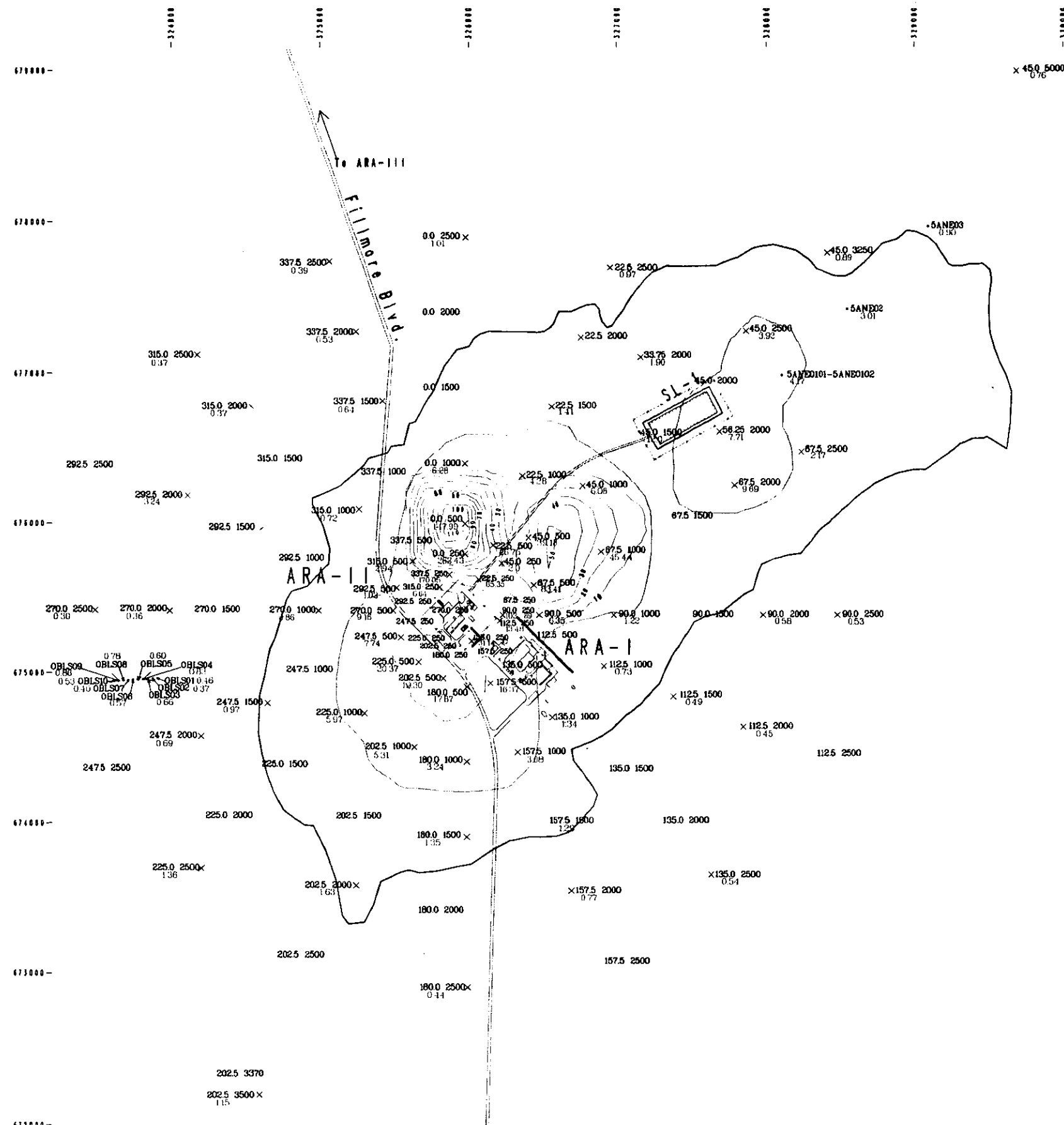
12.8 References

Berry et al., 1993, *Sampling and Analysis Plan for Phase I of the Operable Unit 10-06 Radionuclide-Contaminated Soils Remedial Investigation/Feasibility Study*, EGG-ER-10770, EG&G Idaho, Inc. August.

Bowman et al., 1984, *INEL Environmental Characterization Report*, Volume 2, EGG-NPR-6688, EG&G Idaho, Inc., September.

Clawson et al., 1988, *Climatology of the Idaho National Engineering Laboratory*, DOE/ID-12118, U.S. Department of Energy, December.

DOE,(U.S. Department of Energy) 1994, *Long-Term Land Use Future Scenarios for the Idaho National Engineering Laboratory (Draft)*, DOE/ID-10440, August.

DOE, 1991, *Draft Environmental Impact Statement for the Siting, Construction, and Operation of New Production Reactor Capacity*, Vol. 2, Sections 1-6, DOE/EIS-01440, U.S. Department of Energy, Idaho Falls, Idaho, April.

DOE, 1984, *INEL Site Environmental Monitoring Data for the Third Quarter, 1984*, Idaho.

EG&G Idaho (EG&G Idaho, Inc.) 1994, *Final Scope of Work for Operable Unit 10-06 Radionuclide-Contaminated Soils Remedial Investigation/Feasibility Study*, EGG-ER-10902, December.

EG&G Idaho, 1990, *Closure Plan for the ARA-I Chemical Evaporation Pond (COCA Unit ARA-01)*, EGG-WM-9114, EG&G Idaho, Inc., Idaho Falls, Idaho.

EG&G Idaho, 1993, *Final Scope of Work for Operable Unit 10-06 Radionuclide - Contaminated Soils Remedial Investigation/Feasibility Study*, EGG-ER-10902, December.

EMI (EG&G Energy Measurements, Inc.), 1992, *Idaho National Engineering Laboratory Aerial Radiological Survey Preliminary Report*, NRD-92-419, November.

EPA, (U.S. Environmental Protection Agency) 1994a, *Considering Land Use in the CERCLA Remedy Selection Process*, OSWER Directive No. 9355.7-04.

EPA, 1994b, *Health Effects Assessment Summary Tables, FY-1994, Supplement No. 2*, PB94 921102, November.

EPA, 1994c, *Estimating Radiogenic Cancer Risks*, EPA 402-R-93-076, June.

EPA, 1994d, *Integrated Risk Information System, On-line Computer database*.

EPA, 1992, *Supplemental Guidance to RAGS: Calculating the Concentration Term*, OSWER Directive 9285.7-081, May.

EPA, 1991a, *GEO-EAS 1.2.1 User's Guide*, EPA 600/8-91/008, U.S. Environmental Protection Agency.

EPA, 1991b, *Supplemental Guidance for Superfund Risk Assessments in Region 10,* August 23.

EPA, 1989, *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part A)*, EPA/540/1-89-002, December.

Gilbert, 1987, *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrund Reinhold Company, New York.

Gombert, D., T. K. Honeycutt, J. H. Goettsche, G. M. Huestis, 1993, *Technical Memorandum for the WAG 3 and WAG 10 Soils Treatability Study: Physical Separation of Radionuclides in Soils*, EGG-ER-11101, EG&G Idaho, Inc., December.

Hampton, N. L., R. L. VanHorn, E. J. Mooney, T. A. Bensen, C. S. Staley, and T. S. Green, 1994, *WAG 2 Screening Level Ecological Risk Assessment*, EGG-ER-11398, EG&G Idaho, Inc., Idaho.

Hardy, C. K. and S. N. Stanisich, 1990, *Closure Plan for the ARA-I Chemical Evaporation Pond (COCA Unit ARA-01)*, EGG-WM-9114, EG&G Idaho, Inc., Idaho.

Holdren, K. J., R. G. Filemyr, D. W. Vetter, 1995, *Remedial Investigation/Feasibility Study Report for Operable Units 5-05 and 6-01 (SL-1 and BORAX-I Burial Grounds)*, INEL-95/0027, March.

Honeycutt, T. K., 1994, *Technical Work Plan for the WAG 3 and WAG 10 Radionuclide-Contaminated Soils Treatability Study*, EGG-ER-1192, Draft, EG&G Idaho, Inc., February.

IAEA (International Atomic Energy Agency), 1992, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Standards*, Technical Report Series No. 332.

Jessmore P. G., S. M. Rood, T. J. Haney, M. L. Paarman, R. L. VanHorn, G. A. Harris, I. E. Stepan, S. M. Burns, *Remedial Investigation/Feasibility Study Report for Operable Unit 10-06: Radionuclide-Contaminated Soils at the Idaho National Engineering Laboratory (Draft), Volumes I, II, and III*, INEL-94/0037 Revision 0, April 1995.

McBride, D. W., 1992, *SL-1 Spring Surface Radiation Survey*, RWMC-09-92, EG&G Idaho, Inc., April 30.

Mitchell, R. G., 1994, *The Idaho National Engineering Laboratory Site Environmental Report for Calendar Year 1993*, DOE/ID-12082(93) July.

Pickett, S. L. and M. J. Spry, 1991, *Closure Plan for the ARA-III ARA-740 Sanitary Sewer Leach Field (ARA-13)*, EGG-WM-9471, EG&G Idaho, Inc.

Rood S. M., G. A. Harris, and G. J. White, 1995, *Background Dose Equivalent Rates and Surficial Soil Metal and Radionuclide Concentrations for the Idaho National Engineering Laboratory*, INEL-94/0250, Rev. 0, February.

Sehlke G. and F.E. Bickford, 1993, *Idaho National Engineering Laboratory Groundwater Monitoring Plan*, DOE/ID-10441, U.S. Department of Energy, June.

VanHorn, R. L., N. L. Hampton, and R. C. Morris, 1995, *Guidance Manual for Conducting Screening Level Ecological Risk Assessments at the INEL*, INEL-95/0190, April.

Wilhelmsen, R. N., 1987a, *RWMC and SL-1 Fall Surface Radiation Survey*, RNW-22-87, November 3.

Wilhelmsen, R. N., 1987b, *RWMC and SL-1 Spring Surface Radiation Survey*, RNW-09-87, performed by EG&G Idaho for the Idaho National Engineering Laboratory, May 19.

Wright, K. C. 1989a, *SL-1 Fall Surface Radiation Survey*, KCW-43-89, September 27.

Wright, K. C. 1989b, *SL-1 Spring Surface Radiation Survey*, KCW-27-89, July 11.

Wright, K. C. 1990, *SL-1 Spring Surface Radiation Survey*, KCW-20-90, May 24.

Appendix A

Soil Data

	Sample Location		GPS Survey Location					RESL Location						Activity in Picocuries per gram								
														Am-241					Co-60			
	Sample Number	Nearest Facility	Latitude Deg:Min:Sec	Longitude Deg:Min:Sec	Northing Feet	Easting Feet	Elevation Feet	Degrees Compass	Distance Feet	Sample Date	Years Elapsed	Sample Depth	Siev Mes Size	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value
9	0° 1000'	ARA						0	1000	12/31/85	8.753	0-5 cm		0.003	0.002			0.003				
10	0° 1000'	ARA						0	1000	12/31/85	8.753	0-10 cm										
11	0° 2500'	ARA	43:31:29.51685	112:49:24.93424	677875	481936	5064.5	0	2500	12/31/85	8.753	0-10 cm										
12	0° 500'	ARA						0	500	12/31/77	16.759	0-5 cm										
13	0° 500'	ARA						0	500	12/31/77	16.759	5-10 cm							0.055	0.011	0.033	0.022
14	0° 500'	ARA						0	500	12/31/77	16.759	0-10 cm										
15	0° 2500'	ARA						0	2500	12/31/77	16.759	5-10 cm										
16	0° 2500'	ARA						0	2500	12/31/77	16.759	0-10 cm										
17	0° 1000'	ARA						0	1000	12/31/77	16.759	0-10 cm										
18	0° 1500'	ARA						0	1500	12/31/77	16.759	0-5 cm										
20	0° 250'	ARA						0	250	12/31/77	16.759	0-5 cm		0.01	0.002	0.01	0.00	0.01	0.37	0.06	0.25	0.19
21	0° 250'	ARA						0	250	12/31/77	16.759	0-10 cm		0.01	0.0015	0.00	0.00	0.00	0.525	0.07	0.39	0.32
22	112.5° 2000'	ARA	43:30:57.47472	112:48:59.20914	674616	483806	5084.8	112.5	2000	12/31/91	2.751	0-10 cm										
23	112.5° 1500'	ARA								12/31/85	8.753	5-10 cm										
24	112.5° 1500'	ARA						112.5	1500	12/31/85	8.753	0-10 cm										
25	112°-112.5° 250	ARA						112	250	12/31/77	16.759	0-10 cm										
26	112° 1000'	ARA						112	1000	12/31/77	16.759	0-5 cm										
27	112° 1000'	ARA						112	1000	12/31/77	16.759	0-10 cm										
28	112° 2000'	ARA						112	2000	12/31/77	16.759	0-10 cm										
29	135.0° 2500'	ARA	43:30:47.74242	112:49: 2.03205	673632	483591	5073.1	135	2500	12/31/91	2.751	0-10 cm										
30	135° 250'	ARA						135	250	12/31/77	16.759	0-10 cm							0.039	0.012	0.016	0.004
31	135° 1000'	ARA						135	1000	12/31/77	16.759	0-10 cm										
32	135° 2500'	ARA	43:30:47.74242	112:49:02.03205	673632	483591	5073.1	135	2500	12/31/85	8.753	0-10 cm										
33	135° 1000'	ARA						135	1000	12/31/85	8.753	0-10 cm										
34	135° 2500'	ARA						135	2500	12/31/77	16.759	0-5 cm										
36	157.5° 1500'	ARA						157.5	1500	12/31/91	2.751	0-5 cm										
38	22°-22.5° 250	ARA						22	250	12/31/77	16.759	0-10 cm		0.0165	0.0025	0.01	0.01	0.02				
39	22° 500'	ARA						22	500	12/31/77	16.759	0-5 cm							0.14	0.05	0.04	
40	22° 500'	ARA						22	500	12/31/77	16.759	0-10 cm										
41	22° 1000'	ARA						22	1000	12/31/77	16.759	5-10 cm										
42	22° 1000'	ARA						22	1000	12/31/77	16.759	0-10 cm										
43	22° 2000'	ARA						22	2000	12/31/77	16.759											
44	22° 2500'	ARA						22	2500	12/31/77	16.759	0-5 cm										
46	22.5° 1500'	ARA						22.5	1500	12/31/85	8.753	0-10 cm										
47	22.5° 2500'	ARA	43:31:27.61949	112:49:11.72989	677675	482908	5063	22.5	2500	12/31/85	8.753	0-5 cm		0.006	0.003	0.00		0.01				
48	22.5° 2500'	ARA	43:31:27.61949	112:49:11.72989	677675	482908	5063	22.5	2500	12/31/85	8.753	0-10 cm										

Activity in Picocuries per gr

Sample Loca

Sample Number		Current Activity	Cs-134					Cs-137					K-40					Pb-212					Pb-214			
			Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value
0°	1000'							7.3	0.3	6.7	6.4	6.0	18.1	1.3	15.5	14.2	18.1	1.58	0.14	1.30	1.16	0.00	1.36	0.16	1.04	0.88
0°	1000'							4.265	0.20	3.88	3.68	3.49	17.3	1.2	14.9	13.7	17.3	1.44	0.125	1.19	1.06	0.00	1.18	0.13	0.92	0.79
0°	2500'							1.21	0.085	1.04	0.96	0.99	15.7	1.15	13.4	12.2	15.6	1.31	0.11	1.09	0.98	0.00	1.09	0.12	0.85	0.73
0°	500'							373	11	351	340	254														
0°	500'	0.006						61.8	1.7	58.4	56.7	42.1														
0°	500'							217.4	6.4	204.7	198.4	148.0														
0°	2500'							0.12	0.05	0.02		0.08														
0°	2500'							1.50	0.07	1.36	1.29	1.02														
0°	1000'							13.32	0.42	12.48	12.06	9.07														
0°	1500'							5.5	0.2	5.1	4.9	3.7														
0°	250'	0.04						71	2	67	65	48														
0°	250'	0.06						385.5	11	364	353	262														
112.5°	2000'							0.67	0.055	0.56	0.51	0.63	17.5	1.1	15.3	14.2	17.5									
112.5°	1500'							0.11	0.05	0.01		0.09	15.6	1.2	13.2	12.0	15.6	1.4	0.12	1.2	1.0	0.0	1.09	0.12	0.85	0.73
112.5°	1500'							0.605	0.065	0.48	0.41	0.49	15.6	1.1	13.4	12.3	15.5	1.36	0.11	1.14	1.03	0.00	1.12	0.115	0.89	0.77
112°-112.5°	250							19.81	0.6	18.61	18.01	13.48														
112°	1000'							1.97	0.06	1.85	1.79	1.34														
112°	1000'							1.07	0.038	1.00	0.96	0.73														
112°	2000'							0.39	0.05	0.29	0.24	0.27														
135.0°	2500'							0.63	0.055	0.52	0.47	0.59	17.0	1.1	14.9	13.8	16.9									
135°	250'	0.004						45.75	1.2	43.5	42.3	31.1														
135°	1000'							1.563	0.053	1.458	1.406	1.064														
135°	2500'							0.605	0.07	0.47	0.40	0.49	16.8	1.3	14.3	13.1	16.8	1.71	0.125	1.46	1.33	0.00	1.34	0.13	1.08	0.95
135°	1000'							1.965	0.12	1.73	1.61	1.61	17.1	0.715	15.6	14.9	17.0	1.55	0.125	1.30	1.17	0.00	1.43	0.14	1.15	1.01
135°	2500'							0.81	0.03	0.75	0.72	0.55														
157.5°	1500'							2.3	0.11	2.1	2.0	2.2	18.7	1.1	16.5	15.4	18.7									
22°-22.5°	250'							96	3	90	87	65														
22°	500'	0.02						76	2	72	70	52														
22°	500'							39.3	1.04	37.2	36.2	26.8														
22°	1000'							0.97	0.03	0.91	0.88	0.66														
22°	1000'							6.285	0.215	5.86	5.64	4.28														
22°	2000'							1.66	0.08	1.50	1.42	1.13														
22°	2500'							2.16	0.07	2.02	1.95	1.47														
22.5°	1500'							1.725	0.11	1.51	1.40	1.41	15.6	1.1	13.4	12.3	15.5	1.67	0.125	1.42	1.29	0.00	1.06	0.12	0.82	0.70
22.5°	2500'							2.27	0.13	2.01	1.88	1.86	19.6	1.4	16.8	15.4	19.6	1.74	0.13	1.48	1.35	0.00	1.4	0.14	1.1	1.0
22.5°	2500'							1.19	0.085	1.02	0.94	0.97	17.9	1.3	15.4	14.1	17.8	1.53	0.12	1.29	1.17	0.00	1.2	0.125	1.0	0.8

Sample Loca

	A	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS
	Sample		Pu-238					Pu-239					Pu-240					Sr-90					U-23		
	Number	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma
		Activity	Value	(+/-)	Value	Value	Activity	Value	(+/-)	Value	Value	Activity	Value	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Value	(+/-)	Value
9	0° 1000'	0.00	0.0012	0.0013			0.0011	0.014	0.002	0.010	0.008	0.014	0.014	0.002	0.010	0.008	0.014	2.23	0.11	2.01	1.90	1.80	0.05	0.025	0.00
10	0° 1000'	0.00																1.42	0.105	1.21	1.10	1.14			
11	0° 2500'	0.00																							
12	0°· 500'																	57	2	53	51	38			
13	0° 500'																								
14	0° 500'																								
15	0° 2500'																						0.15	0.06	0.03
16	0° 2500'																								
17	0° 1000'																								
18	0° 1500'																								
19																									
20	0° 250'		0.024	0.003	0.018	0.015	0.021	0.047	0.004	0.039	0.035	0.047	0.047	0.004	0.039	0.035	0.047								
21	0° 250'		0.015	0.0025	0.010	0.008	0.013	0.028	0.003	0.022	0.019	0.027	0.028	0.003	0.022	0.019	0.027								
22	112.5° 2000'	0.00																							
23	112.5° 1500'	0.00																-0.07	0.09			-0.06			
24	112.5° 1500'	0.00																							
25	112°-112.5° 250																								
26	112° 1000'																								
27	112° 1000'																								
28	112° 2000'																								
29	135.0° 2500'																								
30	135° 250'																								
31	135° 1000'																								
32	135° 2500'	0.00																0.25	0.07	0.11	0.04	0.20			
33	135° 1000'	0.00																0.47	0.07	0.33	0.26	0.38			
34	135° 2500'																								
35																									
36	157.5° 1500'																								
37																									
38	22°-22.5° 250'		0.0023	0.0018			0.0020	0.016	0.0025	0.011	0.009	0.016	0.016	0.0025	0.011	0.009	0.016								
39	22° 500'																								
40	22° 500'																								
41	22° 1000'																								
42	22° 1000'																								
43	22° 2000'																								
44	22° 2500'																								
45																									
46	22.5° 1500'	0.00																							
47	22.5° 2500'	0.0	0.003	0.002			0.003	0.021	0.003	0.015	0.012	0.021	0.021	0.003	0.015	0.012	0.021	0.74	0.07	0.60	0.53	0.60	0.053	0.027	
48	22.5° 2500'	0.0																0.40	0.075	0.25	0.17	0.32			

Sample Loca

	A	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR
5	Sample					U-238					Mn-54					Sb-125					Be-7					Eu-15
6	Number	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma
7		Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Value	(+/-)	Value
9	0° 1000'		0.05	1.04	0.04	0.96	0.92	1.04																		
10	0° 1000'																									
11	0° 2500'																									
12	0° 500'																									
13	0° 500'																									
14	0° 500'																									
15	0° 2500'		0.15																							
16	0° 2500'																									
17	0° 1000'																									
18	0° 1500'																									
20	0° 250'																									
21	0° 250'																									
22	112.5° 2000'																									
23	112.5° 1500'																									
24	112.5° 1500'																									
25	112°-112.5° 250																									
26	112° 1000'													1	0.4	0		0								
27	112° 1000'																									
28	112° 2000'																									
29	135.0° 2500'																									
30	135° 250'																									
31	135° 1000'																									
32	135° 2500'																									
33	135° 1000'																									
34	135° 2500'																									
36	157.5° 1500'																									
38	22°-22.5° 250'																									
39	22° 500'																									
40	22° 500'																									
41	22° 1000'																									
42	22° 1000'																									
43	22° 2000'																									
44	22° 2500'																									
46	22.5° 1500'																									
47	22.5° 2500'		0.053	1.06	0.04	0.98	0.94	1.06																		
48	22.5° 2500'																									

	A	CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP
						Eu-155					Pa-234m					Ru-106					Sc-46				
5	Sample Number	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)
9	0° 1000'																							1.01	0.04
10	0° 1000'																								
11	0° 2500'																								
12	0° 500'																								
13	0° 500'																								
14	0° 500'																								
15	0° 2500'																								
16	0° 2500'																								
17	0° 1000'			0.145	0.06	0.04		0.01																	
18	0° 1500'																								
19																									
20	0° 250'																		0.36	0.14	0.08		0.00		
21	0° 250'																								
22	112.5° 2000'																								
23	112.5° 1500'								14	5	4		0												
24	112.5° 1500'																								
25	112°-112.5° 250			0.26	0.04	0.18	0.14	0.03																	
26	112° 1000'																								
27	112° 1000'																								
28	112° 2000'																								
29	135.0° 2500'																								
30	135° 250'																								
31	135° 1000'																								
32	135° 2500'																								
33	135° 1000'																								
34	135° 2500'																								
35																									
36	157.5° 1500'																								
37																									
38	22°-22.5° 250'																								
39	22° 500'																								
40	22° 500'																								
41	22° 1000'			0.06	0.06			0.01																	
42	22° 1000'																								
43	22° 2000'																								
44	22° 2500'																								
45																									
46	22.5° 1500'																								
47	22.5° 2500'																								0.94	0.03
48	22.5° 2500'																								

	A		DQ	DR	DS	DT	DU	DV	DW	DX
1										
2										
3	Sample Loca									
4										
5	Sample		U-233					U-234		
6	Number		2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current
7			Value	Value	Activity	Valu	(+/-)	Value	Value	Activity
8										
9	0°	1000'	0.93	0.89	1.01	1.01	0.04	0.93	0.89	1.01
10	0°	1000'								
11	0°	2500'								
12	0°	500'								
13	0°	500'								
14	0°	500'								
15	0°	2500'								
16	0°	2500'								
17	0°	1000'								
18	0°	1500'								
19										
20	0°	250'								
21	0°	250'								
22	112.5°	2000'								
23	112.5°	1500'								
24	112.5°	1500'								
25	112°-112.5°	250								
26	112°	1000'								
27	112°	1000'								
28	112°	2000'								
29	135.0°	2500'								
30	135°	250'								
31	135°	1000'								
32	135°	2500'								
33	135°	1000'								
34	135°	2500'								
35										
36	157.5°	1500'								
37										
38	22°-22.5°	250'								
39	22°	500'								
40	22°	500'								
41	22°	1000'								
42	22°	1000'								
43	22°	2000'								
44	22°	2500'								
45										
46	22.5°	1500'								
47	22.5°	2500'	0.88	0.85	0.94	0.94	0.03	0.88	0.85	0.94
48	22.5°	2500'								

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
	Sample Location		GPS Survey Location					RESL Location						Activity in Picocuries per gram								
	Sample Number	Neares Facility	Latitude Deg:Min:Sec	Longitude Deg:Min:Sec	Northing Feet	Easting Feet	Elevation Feet	Degrees Compass	istanc Feet	Sample Date	Years Elapsed	Sample Depth	Siev Mes Size	Am-241					Co-60			
														Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value
49	33.75° 2000'	ARA						33.75	2000	12/31/85	8.753	0-10 cm										
50	45° 250'	ARA						45	250	12/31/77	16.759	5-10 cm										
51	45° 250'	ARA						45	250	12/31/77	16.759	0-5 cm		0.005	0.003			0.005	0.16	0.04	0.08	0.04
52	45° 250'	ARA						45	250	12/31/77	16.759	0-10 cm										
53	45° 500'	ARA						45	500	12/31/77	16.759	0-5 cm		0.0054	0.0016	0.0022	0.0006	0.0053				
54	45° 500'	ARA						45	500	12/31/77	16.759	0-10 cm										
55	45° 1000'	ARA						45	1000	12/31/85	8.753	0-10 cm										
56	45° 1000'	ARA						45	1000	12/31/77	16.759	0-10 cm										
57	45° 1500'	ARA						45	1500	12/31/77	16.759	0-5 cm		0.004	0.001	0.002	0.001	0.004				
58																						
59	45° 2500'	ARA	43:31:23.57081	112:48:59.29440	677258	483821	5066.7	45	2500	12/31/85	8.753	0-5 cm										
60	45° 2500'	ARA	43:31:23.57081	112:48:59.29440	677258	483821	5066.7	45	2500	12/31/85	8.753	0-10 cm										
61	45° 2500'	ARA						45	2500	12/31/77	16.759	0-5 cm		0.005	0.001	0.003	0.002	0.005				
62	45° 2500'	ARA						45	2500	12/31/77	16.759	5-10 cm										
63	45° 2500'	ARA						45	2500	12/31/77	16.759	0-10 cm										
64	45° 3250'	ARA						45	3250	12/31/85	8.753	0-10 cm										
65	45° 5000'	ARA						45	5000	12/31/77	16.759	0-5 cm							0.043	0.009	0.025	0.016
66	45° 5000'	ARA						45	5000	12/31/77	16.759	0-10 cm										
67	56.25° 2000'	ARA						56.25	2000	12/31/85	8.753	0-5 cm										
68	56.25° 2000'	ARA						56.25	2000	12/31/85	8.753	0-10 cm										
69	67° 500'	ARA						67	500	12/31/77	16.759	0-5 cm							0.083	0.013	0.057	0.044
70	67° 500'	ARA						67	500	12/31/77	16.759	0-10 cm										
71	67° 1000'	ARA						67	1000	12/31/77	16.759	0-10 cm										
72	67° 2000'	ARA						67	2000	12/31/77	16.759	0-10 cm										
73	67° 2500'	ARA						67	2500	12/31/77	16.759	0-10 cm										
74	67.5° 500'	ARA						67.5	500	12/31/85	8.753	0-5 cm		0	0.002			0				
75	67.5° 500'	ARA						67.5	500	12/31/85	8.753	0-10 cm										
76	67.5° 2000'	ARA						67.5	2000	12/31/85	8.753	0-5 cm		0.003	0.002			0.003				
77	67.5° 2000'	ARA						67.5	2000	12/31/85	8.753	0-10 cm										
78	90° 250'	ARA						90	250	12/31/77	16.759	0-5 cm							0.3	0.015	0.3	0.3
79	90° 250'	ARA						90	250	12/31/77	16.759	5-10 cm										
80	90° 250'	ARA						90	250	12/31/77	16.759	0-10 cm										
81	90° 500'	ARA						90	500	12/31/77	16.759	0-5 cm		0.008	0.002	0.004	0.002	0.008				
82	90° 500'	ARA						90	500	12/31/77	16.759	0-10 cm										
83	90° 1000'	ARA						90	1000	12/31/85	8.753	0-10 cm										
84	90° 1000'	ARA						90	1000	12/31/77	16.759	0-10 cm										
85	90° 1500'	ARA						90	1500	12/31/77	16.759	0-5 cm										
86																						
87	90° 2000'	ARA	43:31:04.92485	112:48:57.49581	675369	483939	5071.6	90	2000	12/31/85	8.753	0-10 cm										
88	90.0° 2500'	ARA	43:31: 4.96469	112:48:50.69827	675369	484439	5076.3	90	2500	12/31/91	2.751	0-10 cm										
89	90° 2500'	ARA						90	2500	12/31/77	16.759	0-10 cm										

Activity in Picocuries per gr

Sample Loca

		Cs-134					Cs-137					K-40					Pb-212					Pb-214			
Sample Number	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value
33.75° 2000'							2.32	0.135	2.05	1.92	1.90	17.0	1.2	14.6	13.4	16.9	1.39	0.12	1.15	1.03	0.00	1.14	0.12	0.90	0.78
45° 250'		0.1	0.04	0.0		0.0	4.41	0.18	4.05	3.87	3.00														
45° 250'	0.02						1.46	0.19	1.08	0.89	0.99														
45° 250'							2.935	0.185	2.57	2.38	2.00														
45° 500'							109	3	103	100	74														
45° 500'							57.56	1.60	54.37	52.77	39.18														
45° 1000'							7.305	0.315	6.68	6.36	5.98	17.4	1.2	15.0	13.8	17.3	1.54	0.13	1.28	1.15	0.00	1.29	0.16	0.97	0.81
45° 1000'							9.085	0.275	8.54	8.26	6.18														
45° 1500'							17.6	0.5	16.6	16.1	12.0														
45° 2500'							9.5	0.4	8.7	8.3	7.8	14.8	1.1	12.6	11.5	14.8	1.53	0.14	1.25	1.11	0.00	0.99	0.16	0.67	0.51
45° 2500'							5.3	0.24	4.8	4.6	4.3	14.6	1.1	12.5	11.5	14.6	1.30	0.12	1.06	0.94	0.00	1.03	0.13	0.77	0.64
45° 2500'							9.8	0.3	9.2	8.9	6.7														
45° 2500'							0.48	0.02	0.44	0.42	0.33														
45° 2500'							5.14	0.16	4.82	4.66	3.50														
45° 3250'							1.085	0.08	0.93	0.85	0.89	16.5	1.2	14	13	16	1.54	0.12	1.30	1.18	0.00	1.12	0.12	0.88	0.76
45° 5000'	0.005						2.13	0.07	1.99	1.92	1.45														
45° 5000'							1.118	0.041	1.037	0.997	0.761														
56.25° 2000'							16.8	0.7	15.4	14.7	13.7	17.2	1.2	14.8	13.6	17.2	1.6	0.15	1.3	1.2	0.0	1	0.2	1	0
56.25° 2000'							9.425	0.41	8.61	8.20	7.71	16.3	1.1	14.1	13.0	16.2	1.49	0.13	1.23	1.10	0.00	1.18	0.16	0.86	0.70
67° 500'	0.009	0.14	0.03	0.08	0.05	0.00	241	7	227	220	164														
67° 500'							130.3	3.8	122.7	118.9	88.7														
67° 1000'							66.75	2.2	62.4	60.2	45.4														
67° 2000'							17.29	0.535	16.22	15.68	11.77														
67° 2500'							3.185	0.13	2.93	2.80	2.17														
67.5° 500'							133	5	123	118	109	11.7	1	9.7	8.7	11.7	0.7	0.3	0.1		0.0	0.8	0.3	0.2	
67.5° 500'							95.55	3.6	88.4	84.8	78.2	11.1	1.0	9.2	8.3	11.1	0.8	0.3	0.3	0.1	0.0	1.05	0.3	0.5	0.2
67.5° 2000'							14.8	0.6	13.6	13.0	12.1	13	1	11	10	13	1.29	0.13	1.03	0.90	0.00	1.57	0.16	1.25	1.09
67.5° 2000'							9.31	0.39	8.53	8.14	7.62	12.9	1.0	11.0	10.0	12.8	1.16	0.115	0.93	0.81	0.00	1.18	0.135	0.91	0.77
90° 250'	0.0						9.3	0.2	8.9	8.7	6.3														
90° 250'							293	9	275	266	199														
90° 250'							151.2	4.6	142.0	137.4	102.9														
90° 500'		0.046	0.01	0.026	0.016	0.000	17.7	0.5	16.7	16.2	12.0														
90° 500'							9.33	0.265	8.80	8.54	6.35														
90° 1000'							1.47	0.10	1.27	1.17	1.20	15.8	1.2	13.5	12.3	15.7	1.35	0.115	1.12	1.01	0.00	1.22	0.125	0.97	0.84
90° 1000'							1.835	0.055	1.73	1.67	1.25														
90° 1500'							1.18	0.09	1.00	0.91	0.80														
90° 2000'							0.71	0.07	0.57	0.50	0.58	15.7	1.1	13.5	12.4	15.7	1.43	0.115	1.20	1.08	0.00	1.32	0.125	1.07	0.95
90.0° 2500'							0.82	0.065	0.69	0.63	0.77	18.6	1.1	16.4	15.3	18.5									
90° 2500'							0.425	0.055	0.32	0.26	0.29														

Sample Loca

Sample Number	Pu-238					Pu-239					Pu-240					Sr-90					U-23			
	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value
33.75° 2000'	0.00																							
45° 250'																								
45° 250'		0.004	0.001	0.002	0.001	0.004	0.016	0.002	0.012	0.010	0.016	0.016	0.002	0.012	0.010	0.016								
45° 250'																								
45° 500'		0.025	0.003	0.019	0.016	0.022	0.033	0.003	0.027	0.024	0.033	0.033	0.003	0.027	0.024	0.033								
45° 500'																								
45° 1000'	0.00																1.94	0.12	1.70	1.58	1.57			
45° 1000'																								
45° 1500'		0.003	0.001	0.001	0.000	0.003	0.015	0.002	0.011	0.009	0.015	0.015	0.002	0.011	0.009	0.015								
45° 2500'	0.00																1.73	0.09	1.55	1.46	1.40			
45° 2500'	0.00																1.14	0.10	0.94	0.84	0.92			
45° 2500'		0	0.001			0.000	0.018	0.002	0.014	0.012	0.018	0.018	0.002	0.014	0.012	0.018								
45° 2500'																						0.122	0.018	0.086
45° 2500'																								
45° 3250'	0.00																							
45° 5000'																								
45° 5000'																								
56.25° 2000'	0																							
56.25° 2000'	0.00																							
67° 500'																								
67° 500'																								
67° 1000'																								
67° 2000'																								
67° 2500'																								
67.5° 500'	0.0	0.002	0.002			0.002	0.009	0.002	0.005	0.003	0.009	0.009	0.002	0.005	0.003	0.009	22.3	0.7	20.9	20.2	18.0	0.043	0.021	0.001
67.5° 500'	0.0																19.9	0.7	18.5	17.8	16.1			
67.5° 2000'	0.00	0.001	0.0013			0.0009	0.011	0.002	0.007	0.005	0.011	0.011	0.002	0.007	0.005	0.011	17.3	0.5	16.3	15.8	14.0	0.053	0.027	
67.5° 2000'	0.00																9.78	0.32	9.14	8.82	7.91			
90° 250'																								
90° 250'																								
90° 250'																								
90° 500'		0.001	0.001			0.001	0.021	0.003	0.015	0.012	0.021	0.021	0.003	0.015	0.012	0.021								
90° 500'																								
90° 1000'	0.00																							
90° 1000'																								
90° 1500'																								
90° 2000'	0.00																							
90.0" 2500'																								
90° 2500'																								

Sample Loca

	A	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR
	Sample		U-238								Mn-54						Sb-125						Be-7			Eu-15
	Number	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value
49	33.75° 2000'																										
50	45° 250'																									
51	45° 250'																									
52	45° 250'																									
53	45° 500'																									
54	45° 500'																									
55	45° 1000'																									
56	45° 1000'																									
57	45° 1500'																									
58																										
59	45° 2500'																		130	30	70	40	0			
60	45° 2500'																									
61	45° 2500'																									
62	45° 2500'	0.068	0.122																							
63	45° 2500'																									
64	45° 3250'																									
65	45° 5000'																									
66	45° 5000'																									
67	56.25° 2000'																							0.6	0.15	0.3
68	56.25° 2000'																									
69	67° 500'																									
70	67° 500'																									
71	67° 1000'																									
72	67° 2000'																									
73	67° 2500'																									
74	67.5° 500'		0.043	0.84	0.03	0.78	0.75	0.84																		
75	67.5° 500'																									
76	67.5° 2000'		0.053	1.01	0.04	0.93	0.89	1.01																		
77	67.5° 2000'																									
78	90° 250'																									
79	90° 250'									0.16	0.07	0.02		0.00												
80	90° 250'																									
81	90° 500'																									
82	90° 500'																									
83	90° 1000'																									
84	90° 1000'																									
85	90° 1500'																									
86																										
87	90° 2000'																									
88	90.0° 2500'																									
89	90° 2500'																									

Sample Loca

	A		CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP
	Sample Number						Eu-155					Pa-234m					Ru-106					Sc-46				
			3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)
49	33.75°	2000'																								
50	45°	250'																								
51	45°	250'																								
52	45°	250'																								
53	45°	500'																								
54	45°	500'																								
55	45°	1000'																								
56	45°	1000'																								
57	45°	1500'																								
58																										
59	45°	2500'																								
60	45°	2500'																								
61	45°	2500'																								
62	45°	2500'																								
63	45°	2500'																								
64	45°	3250'																								
65	45°	5000'																								
66	45°	5000'																								
67	56.25°	2000'	0.2	0.4																						
68	56.25°	2000'																								
69	67°	500'			0.39	0.12	0.15	0.03	0.04																	
70	67°	500'																								
71	67°	1000'																								
72	67°	2000'																								
73	67°	2500'																								
74	67.5°	500'																							0.8	0.03
75	67.5°	500'																								
76	67.5°	2000'																							0.91	0.03
77	67.5°	2000'																								
78	90°	250'			0.18	0.04	0.10	0.06	0.02						0.49	0.19	0.11		0.00							
79	90°	250'																								
80	90°	250'																								
81	90°	500'																								
82	90°	500'																								
83	90°	1000'																								
84	90°	1000'																								
85	90°	1500'																								
86																										
87	90°	2000'																								
88	90.0°	2500'																								
89	90°	2500'																								

	A		DQ	DR	DS	DT	DU	DV	DW	DX
1										
2										
3	Sample Loca									
4										
5	Sample		U-233					U-234		
6	Number		2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current
7			Value	Value	Activity	Valu	(+/-)	Value	Value	Activity
49	33.75°	2000'								
50	45°	250'								
51	45°	250'								
52	45°	250'								
53	45°	500'								
54	45°	500'								
55	45°	1000'								
56	45°	1000'								
57	45°	1500'								
58										
59	45°	2500'								
60	45°	2500'								
61	45°	2500'								
62	45°	2500'								
63	45°	2500'								
64	45°	3250'								
65	45°	5000'								
66	45°	5000'								
67	56.25°	2000'								
68	56.25°	2000'								
69	67°	500'								
70	67°	500'								
71	67°	1000'								
72	67°	2000'								
73	67°	2500'								
74	67.5°	500'	0.7	0.7	0.8	0.8	0.03	0.7	0.7	0.8
75	67.5°	500'								
76	67.5°	2000'	0.85	0.82	0.91	0.91	0.03	0.85	0.82	0.91
77	67.5°	2000'								
78	90°	250'								
79	90°	250'								
80	90°	250'								
81	90°	500'								
82	90°	500'								
83	90°	1000'								
84	90°	1000'								
85	90°	1500'								
86										
87	90°	2000'								
88	90.0°	2500'								
89	90°	2500'								

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
3	Sample Location		GPS Survey Location					RESL Location						Activity in Picocuries per gram								
5	Sample	Neares	Latitude	Longitude	Northing	Easting	Elevation	Degrees	istanc	Sample	Years	Sample	Siev	Am-241					Co-60			
6	Number	Facility	Deg:Min:Sec	Deg:Min:Sec	Feet	Feet	Feet	Compass	Feet	Date	Elapsed	Depth	Mes	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value
7													Size									
90	157°	500'	ARA						157	500	12/31/77	16.759	0-10 cm										
91	157°	1000'	ARA						157	1000	12/31/77	16.759	0-5 cm							0.025	0.013		
92	157°	1000'	ARA						157	1000	12/31/77	16.759	0-10 cm										
93	157°	2000'	ARA						157	2000	12/31/77	16.759	0-10 cm										
94	157.5°	500'	ARA						157.5	500	12/31/91	2.751	0-10 cm										
95	157.5°	1500'	ARA						157.5	1500	12/31/91	2.751	5-10 cm										
96																							
97	157.5°	2000'	ARA	43:30:46.60273	112:49:14.73010	673524	482654	5021	157.5	2000	12/31/85	8.753	0-10 cm										
98	180°	500'	ARA						180	500	12/31/77	16.759	0-10 cm										
99	180°	1000'	ARA						180	1000	12/31/77	16.759	0-10 cm										
100	180°	1500'	ARA						180	1500	12/31/85	8.753	0-10 cm										
101	180°	1500'	ARA						180	1500	12/31/77	16.759	0-5 cm										
102																							
103	180°	2500'	ARA	43:30:40.26054	112:49:24.13104	672887	481956	5011.4	180	2500	12/31/85	8.753	0-5 cm										
104	180°	2500'	ARA	43:30:40.26054	112:49:24.13104	672887	481956	5011.4	180	2500	12/31/85	8.753	5-10 cm										
105	180°	2500'	ARA	43:30:40.26054	112:49:24.13104	672887	481956	5011.4	180	2500	12/31/85	8.753	0-10 cm										
106	180°	2500'	ARA						180	2500	12/31/77	16.759	0-10 cm										
107	202°	500'	ARA						202	500	12/31/77	16.759	0-5 cm							0.015	0.01		
108	202°	500'	ARA						202	500	12/31/77	16.759	0-10 cm										
109	202°	2000'	ARA						202	2000	12/31/77	16.759	0-10 cm										
110	202.5°	1000'	ARA						202.5	1000	12/31/85	8.753	0-10 cm										
111	202.5°	2000'	ARA	43:30:46.84711	112:49:34.42494	673560	481203	5023.1	202.5	2000	12/31/85	8.753	0-10 cm										
112	202.5°	3370'	ARA	43:30:34.58650	112:49:42.24250	672323	480617	4981.9	202.5	3370		######											
113																							
114	202.5°	3500'	ARA						202.5	3500	12/31/85	8.753	0-10 cm										
115	225°	500'	ARA						225	500	12/31/85	8.753	0-10 cm										
116	225°	500'	ARA						225	500	12/31/77	16.759	0-5 cm		0.002	0.005			0.002	0.06	0.009	0.04	0.03
117	225°	500'	ARA						225	500	12/31/77	16.759	0-10 cm										
118	225°	1000'	ARA						225	1000	12/31/77	16.759	0-10 cm										
119	225°	2500'	ARA	43:30:47.91451	112:49:48.53380	673676	480164	5029.8	225	2500	12/31/85	8.753	0-10 cm										
120	225°	2500'	ARA						225	2500	12/31/77	16.759	0-10 cm										
121	247°	500'	ARA						247	500	12/31/77	16.759	0-10 cm										
122	247°	2000'	ARA						247	2000	12/31/77	16.759	0-10 cm										
123	247.5°	1500'	ARA						247.5	1500	12/31/85	8.753	0-10 cm										
124	270°	500'	ARA						270	500	12/31/77	16.759	0-5 cm		0.003	0.001	0.001	0.000	0.003				
125	270°	500'	ARA						270	500	12/31/77	16.759	0-10 cm										
126	270.0°	1000'	ARA						270	1000	12/31/91	2.751	0-10 cm										
127	270°	1000'	ARA						270	1000	12/31/85	8.753	0-10 cm										
128	270°	1000'	ARA						270	1000	12/31/77	16.759	0-5 cm										
129	270°	1000'	ARA						270	1000	12/31/77	16.759	0-10 cm										
130	270°	1500'	ARA						270	1500	12/31/77	16.759	0-5 cm		0.003	0.001	0.001	0.000	0.003				

Activity in Picocuries per gr

Sample Loca

Sample Number	Cs-134 Current Activity	Cs-134 Data Value	Cs-134 Error (+/-)	Cs-134 2*Sigma Value	Cs-134 3*Sigma Value	Cs-134 Current Activity	Cs-137 Data Value	Cs-137 Error (+/-)	Cs-137 2*Sigma Value	Cs-137 3*Sigma Value	Cs-137 Current Activity	K-40 Data Valu	K-40 Error (+/-)	K-40 2*Sigma Value	K-40 3*Sigma Value	K-40 Current Activity	Pb-212 Data Valu	Pb-212 Error (+/-)	Pb-212 2*Sigma Value	Pb-212 3*Sigma Value	Pb-212 Current Activity	Pb-214 Data Valu	Pb-214 Error (+/-)	Pb-214 2*Sigma Value	Pb-214 3*Sigma Value
157° 500'							20.30	0.54	19.22	18.68	13.82														
157° 1000'	0.003						8.5	0.3	7.9	7.6	5.8														
157° 1000'							4.52	0.16	4.20	4.04	3.08														
157° 2000'							0.925	0.08	0.77	0.69	0.63														
157.5° 500'							20.15	0.8	18.6	17.8	18.9	16.5	1	14.5	13.5	16.5									
157.5° 1500'							0.45	0.05	0.35	0.30	0.42	19.6	1.1	17.4	16.3	19.6									
157.5° 2000'							1.115	0.085	0.95	0.86	0.91	16.4	1.2	14.1	13.0	16.4	1.48	0.115	1.25	1.14	0.00	1.18	0.125	0.93	0.81
180° 500'							26.25	0.8	24.7	23.9	17.9														
180° 1000'							4.76	0.165	4.43	4.27	3.24														
180° 1500'							1.65	0.105	1.44	1.34	1.35	17.1	1.2	14.8	13.6	17.0	1.49	0.12	1.25	1.13	0.00	1.39	0.13	1.13	1.00
180° 1500'							3.87	0.17	3.53	3.36	2.63														
180° 2500'							1.08	0.09	0.90	0.81	0.88	17	1.2	15	13	17	1.4	0.12	1.2	1.0	0.0	1.32	0.13	1.06	0.93
180° 2500'							0.07	0.04			0.06	14.8	1	12.8	11.8	14.8	1.48	0.11	1.26	1.15	0.00	1.19	0.11	0.97	0.86
180° 2500'							0.575	0.065	0.45	0.38	0.47	15.9	1.1	13.7	12.6	15.9	1.44	0.115	1.21	1.10	0.00	1.26	0.12	1.02	0.90
180° 2500'							0.61	0.07	0.47	0.40	0.42														
202° 500'	0.002						26.3	0.8	24.7	23.9	17.9														
202° 500'							28.35	0.9	26.7	25.8	19.3														
202° 2000'							2.923	0.094	2.736	2.642	1.989														
202.5° 1000'							6.50	0.29	5.92	5.63	5.31	16.7	1.2	14.4	13.3	16.7	1.34	0.125	1.09	0.96	0.00	1.05	0.155	0.7	0.6
202.5° 2000'							1.6	0.10	1.4	1.3	1.3	17.9	1.2	15.5	14.3	17.9	1.43	0.12	1.19	1.07	0.00	1.17	0.125	0.92	0.79
202.5° 3370'																									
202.5° 3500'							1.41	0.10	1.22	1.13	1.15	15.6	1.1	13	12	16	1.41	0.12	1.17	1.05	0.00	1.21	0.125	0.96	0.84
225° 500'							25.21	0.99	23.23	22.24	20.62	14.8	1.1	12.6	11.5	14.8	1.22	0.155	0.91	0.75	0.00	1.28	0.21	0.86	0.65
225° 500'	0.01						56.6	1.7	53.2	51.5	38.5														
225° 500'							29.55	0.89	27.8	26.9	20.1														
225° 1000'							8.775	0.265	8.25	7.98	5.97														
225° 2500'							0.985	0.08	0.83	0.75	0.81	15.9	1.2	13.6	12.4	15.8	1.39	0.115	1.16	1.05	0.00	1.15	0.12	0.91	0.79
225° 2500'							2.815	0.14	2.54	2.40	1.92														
247° 500'							11.37	0.365	10.64	10.28	7.74														
247° 2000'							1.02	0.038	0.94	0.91	0.69														
247.5° 1500'							1.18	0.085	1.01	0.93	0.97	17.7	1.2	15.3	14.1	17.7	1.51	0.12	1.27	1.15	0.00	1.35	0.13	1.09	0.96
270° 500'							26.2	0.8	24.6	23.8	17.8														
270° 500'							13.46	0.415	12.63	12.21	9.16														
270.0° 1000'							0.99	0.065	0.86	0.80	0.93	19.2	1.1	17.0	15.9	19.2									
270° 1000'							1.475	0.10	1.28	1.18	1.21	18.0	1.3	15.5	14.3	18.0	1.42	0.12	1.18	1.06	0.00	1.13	0.125	0.88	0.76
270° 1000'							1.24	0.04	1.16	1.12	0.84														
270° 1000'							0.654	0.026	0.603	0.577	0.445														
270° 1500'							1.63	0.06	1.51	1.45	1.11														

Sample Loca

Sample Number		Current Activity	Pu-238					Pu-239					Pu-240					Sr-90					U-23		
			Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value
157°	500'																								
157°	1000'																								
157°	1000'																								
157°	2000'																								
157.5°	500'																								
157.5°	1500'																								
157.5°	2000'	0.00																							
180°	500'																								
180°	1000'																								
180°	1500'	0.00																							
180°	1500'																								
180°	2500'	0.00																0.46	0.06	0.34	0.28	0.37			
180°	2500'	0.00																							
180°	2500'	0.00																							
180°	2500'																								
202°	500'																								
202°	500'																								
202°	2000'																								
202.5°	1000'	0.0																							
202.5°	2000'	0.00																0.61	0.075	0.46	0.39	0.49			
202.5°	3370'																								
202.5°	3500'	0.00																							
225°	500'	0.00																6.17	0.23	5.71	5.48	4.99			
225°	500'		0.004	0.001	0.002	0.001	0.004	0.011	0.002	0.007	0.005	0.011	0.011	0.002	0.007	0.005	0.011								
225°	500'																								
225°	1000'																								
225°	2500'	0.00																0.42	0.08	0.26	0.18	0.34			
225°	2500'																								
247°	500'																								
247°	2000'																								
247.5°	1500'	0.00																							
270°	500'		0.0011	0.0006			0.0010	0.012	0.002	0.008	0.006	0.012	0.012	0.002	0.008	0.006	0.012	0.41	0.05	0.31	0.26	0.27			
270°	500'																	1.21	0.075	1.06	0.98	0.80			
270.0°	1000'																								
270°	1000'	0.00																0.29	0.07	0.15	0.08	0.23			
270°	1000'																								
270°	1000'																								
270°	1500'		0.0011	0.0006			0.0010																		

	A	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR
1																										
2																										
3	Sample Loca																									
4																										
5	Sample				U-238						Mn-54					Sb-125					Be-7					Eu-15
6	Number	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma
7		Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Value	(+/-)	Value
90	157° 500'																									
91	157° 1000'																									
92	157° 1000'																									
93	157° 2000'																									
94	157.5° 500'																									
95	157.5° 1500'																									
96																										
97	157.5° 2000'																									
98	180° 500'																									
99	180° 1000'																									
100	180° 1500'																									
101	180° 1500'																									
102																										
103	180° 2500'																									
104	180° 2500'																									
105	180° 2500'																									
106	180° 2500'																									
107	202° 500'																									
108	202° 500'																									
109	202° 2000'																									
110	202.5° 1000'																									
111	202.5° 2000'																									
112	202.5° 3370'																									
113																										
114	202.5° 3500'																									
115	225° 500'																									
116	225° 500'																									
117	225° 500'																									
118	225° 1000'																									
119	225° 2500'																									
120	225° 2500'																									
121	247° 500'																									
122	247° 2000'																									
123	247.5° 1500'																									
124	270° 500'																									
125	270° 500'																									
126	270.0° 1000'																									
127	270° 1000'																									
128	270° 1000'														0.1	0.04	0.0		0.0							
129	270° 1000'																									
130	270° 1500'																									

	A	CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP
1																									
2																									
3	Sample Loca																								
4																									
5	Sample					Eu-155					Pa-234m					Ru-106					Sc-46				
6	Number	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)
90	157° 500'																								
91	157° 1000'																								
92	157° 1000'																								
93	157° 2000'																								
94	157.5° 500'																								
95	157.5° 1500'																								
96																									
97	157.5° 2000'																								
98	180° 500'																								
99	180° 1000'																								
100	180° 1500'																								
101	180° 1500'																								
102																									
103	180° 2500'																								
104	180° 2500'								12	4	4	0	0												
105	180° 2500'																								
106	180° 2500'																								
107	202° 500'																								
108	202° 500'																								
109	202° 2000'																								
110	202.5° 1000'																								
111	202.5° 2000'																								
112	202.5° 3370'																								
113																									
114	202.5° 3500'																								
115	225° 500'																								
116	225° 500'																								
117	225° 500'																								
118	225° 1000'																								
119	225° 2500'																								
120	225° 2500'																								
121	247° 500'																								
122	247° 2000'																								
123	247.5° 1500'																								
124	270° 500'																								
125	270° 500'																								
126	270.0° 1000'																								
127	270° 1000'																								
128	270° 1000'																								
129	270° 1000'																								
130	270° 1500'																								

	A		DQ	DR	DS	DT	DU	DV	DW	DX
1										
2										
3	Sample Loca									
4										
5	Sample		U-233					U-234		
6	Number		2°Sigma	3°Sigma	Current	Data	Error	2°Sigma	3°Sigma	Current
7			Value	Value	Activity	Valu	(+/-)	Value	Value	Activity
90	157°	500'								
91	157°	1000'								
92	157°	1000'								
93	157°	2000'								
94	157.5°	500'								
95	157.5°	1500'								
96										
97	157.5°	2000'								
98	180°	500'								
99	180°	1000'								
100	180°	1500'								
101	180°	1500'								
102										
103	180°	2500'								
104	180°	2500'								
105	180°	2500'								
106	180°	2500'								
107	202°	500'								
108	202°	500'								
109	202°	2000'								
110	202.5°	1000'								
111	202.5°	2000'								
112	202.5°	3370'								
113										
114	202.5°	3500'								
115	225°	500'								
116	225°	500'								
117	225°	500'								
118	225°	1000'								
119	225°	2500'								
120	225°	2500'								
121	247°	500'								
122	247°	2000'								
123	247.5°	1500'								
124	270°	500'								
125	270°	500'								
126	270.0°	1000'								
127	270°	1000'								
128	270°	1000'								
129	270°	1000'								
130	270°	1500'								

	Sample Location		GPS Survey Location					RESL Location						Activity in Picocuries per gram								
	Sample Number	Nearest Facility	Latitude Deg:Min:Sec	Longitude Deg:Min:Sec	Northing Feet	Easting Feet	Elevation Feet	Degrees Compass	istanc Feet	Sample Date	Years Elapsed	Sample Depth	Siev Mes Size	Am-241					Co-60			
														Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value
131																						
132	270° 2000'	ARA	43:31:04.88987	112:49:51.62275	675397	479950	5060.3	270	2000	12/31/85	8.753	0-10 cm										
133	270° 2500'	ARA						270	2500	12/31/77	16.759	0-10 cm										
134	292 500'	ARA						292	500	12/31/77	16.759	0-5 cm							0.012	0.011		
135	292° 500'	ARA						292	500	12/31/77	16.759	0-10 cm										
136	292° 2000'	ARA						292	2000	12/31/77	16.759	0-10 cm										
137	292.5° 500'	ARA						292.5	500	12/31/85	8.753	0-10 cm										
138	292.5° 2000'	ARA	43:31:12.46186	112:49:50.05396	676163	480072	5045.2	292.5	2000	12/31/85	8.753	0-10 cm										
139	315° 250'	ARA						315	250	12/31/77	16.759	0-10 cm										
140	315 ° 500'	ARA						315	500	12/31/77	16.759	0-5 cm										
141	315° 500'	ARA						315	500	12/31/77	16.759	0-10 cm										
142	315° 1000'	ARA						315	1000	12/31/77	16.759	0-5 cm										
143	315° 1000'	ARA						315	1000	12/31/77	16.759	0-10 cm										
144	315° 1500'	ARA						315	1500	12/31/77	16.759	0-5 cm										
145																						
146	315° 2000'	ARA	43:31:18.36304	112:49:44.39335	676757	480494	5049.9	315	2000	12/31/85	8.753	0-10 cm										
147	315.0° 2500'	ARA	43:31:21.72583	112:49:49.34841	677100	480132	5050.9	315	2500	12/31/91	2.751	0-10 cm										
148	315° 2500'	ARA						315	2500	12/31/77	16.759	0-10 cm										
149	337°-337.5° 250	ARA						337	250	12/31/77	16.759	0-10 cm							0.145	0.025	0.10	0.07
150	337° 500'	ARA						337	500	12/31/77	16.759	5-10 cm										
151																						
152	337° 1000'	ARA						337	1000	12/31/77	16.759	0-5 cm										
153																						
154																						
155	337° 2000'	ARA						337	2000	12/31/77	16.759	0-10 cm										
156	337.5° 1500'	ARA						337.5	1500	12/31/91	2.751	0-10 cm										
157	337.5° 1500'	ARA						337.5	1500	12/31/85	8.753	0-10 cm										
158	337.5° 2500'	ARA	43:31:27.86697	112:49:37.41879	677715	481015	5060.4	337.5	2500	12/31/85	8.753	0-10 cm										
159	0BLS0101	ARA								12/31/93	0.748	0-10 cm		0.02	0.03			0.0199				
160	0BLS0201	ARA								12/31/93	0.748	0-10 cm		0.01	0.02			0.0099				
161	0BLS0301	ARA								12/31/93	0.748	0-10 cm		0.0005	0.016			0.0005				
162	0BLS0401	ARA								12/31/93	0.748	0-10 cm		0.02	0.03			0.0199				
163	0BLS0501	ARA								12/31/93	0.748	0-10 cm		0.0004	0.0104			0.0004				
164	0BLS0601	ARA								12/31/93	0.748	0-10 cm		0.05	0.04			0.0497				
165	0BLS0701	ARA								12/31/93	0.748	0-10 cm		0.0004	0.0102			0.0004				
166	0BLS0801	ARA								12/31/93	0.748	0-10 cm		-4E-04	0.0102			-0.0004				
167	0BLS0901	ARA								12/31/93	0.748	0-10 cm		0.0005	0.0105			0.0005				
168	0BLS1001	ARA								12/31/93	0.748	0-10 cm		0.0005	0.0106			0.0005				
169	5ANE0101	ARA								12/31/93	0.748	0-10 cm										
170	5ANE0201	ARA								12/31/93	0.748	0-10 cm										
171	5ANE0301	ARA								12/31/93	0.748	0-10 cm										

Activity in Picocuries per gr

Sample Loca

A	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
Sample	Cs-134						Cs-137					K-40					Pb-212					Pb-214			
Number	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value
270° 2000'							0.445	0.06	0.33	0.27	0.36	17.3	1.2	14.9	13.7	17.2	1.40	0.11	1.18	1.07	0.00	1.22	0.115	0.99	0.87
270° 2500'							0.435	0.065	0.31	0.24	0.30														
292 500'	0.001						2.66	0.08	2.50	2.42	1.81														
292° 500'							1.474	0.048	1.378	1.330	1.003														
292° 2000'							4.385	0.2	3.99	3.79	2.99														
292.5° 500'							1.265	0.09	1.09	1.00	1.03	17.5	1.2	15.1	13.9	17.5	1.36	0.12	1.12	1.00	0.00	1.21	0.125	0.96	0.83
292.5° 2000'							4.27	0.2	3.87	3.67	3.49	18.3	1.3	15.8	14.5	18.2	1.47	0.125	1.22	1.10	0.00	1.33	0.145	1.04	0.90
315° 250'							0.945	0.037	0.87	0.83	0.64														
315° 500'							8.2	0.2	7.8	7.6	5.6														
315° 500'							4.313	0.110	4.094	3.984	2.936														
315° 1000'							1.94	0.06	1.82	1.76	1.32														
315° 1000'							1.052	0.036	0.980	0.944	0.716														
315° 1500'							0.76	0.08	0.60	0.52	0.52														
315° 2000'							0.45	0.06	0.33	0.27	0.37	16.8	1.2	14.4	13.2	16.8	1.74	0.13	1.48	1.35	0.00	1.21	0.125	0.96	0.84
315.0° 2500'							0.39	0.05	0.29	0.24	0.37	18.1	1.1	15.9	14.8	18.1									
315° 2500'							0.545	0.065	0.42	0.35	0.37														
337°-337.5° 250	0.02						249.8	8.0	233.9	226.0	170.1														
337° 500'							7	0.2	7	6	5														
337° 1000'							44.1	1.3	41.5	40.2	30.0														
337° 2000'							0.777	0.031	0.716	0.686	0.529														
337.5° 1500'							0.655	0.055	0.55	0.49	0.61	18.6	1.1	16.4	15.3	18.6									
337.5° 1500'							0.81	0.075	0.66	0.59	0.66	16.5	1.2	14.2	13.0	16.4	1.39	0.565	0.26		0.00	1.18	0.12	0.94	0.82
337.5° 2500'							0.48	0.055	0.37	0.32	0.39	16.5	1.2	14	13	16	1.49	0.115	1.26	1.14	0.00	1.12	0.12	0.88	0.76
0BLS0101							0.465	0.058	0.35	0.29	0.46														
0BLS0201							0.375	0.044	0.29	0.24	0.37														
0BLS0301							0.672	0.063	0.55	0.48	0.66														
0BLS0401							0.845	0.089	0.67	0.58	0.83														
0BLS0501							0.611	0.063	0.48	0.42	0.60														
0BLS0601							0.583	0.064	0.46	0.39	0.57														
0BLS0701							0.405	0.052	0.30	0.25	0.40														
0BLS0801							0.792	0.074	0.65	0.57	0.78														
0BLS0901							0.87	0.094	0.68	0.59	0.86														
0BLS1001							0.541	0.061	0.42	0.36	0.53														
5ANE0101							4.24	0.347	3.55	3.20	4.17														
5ANE0201							3.06	0.233	2.59	2.36	3.01														
5ANE0301							0.919	0.094	0.73	0.64	0.90														

	A	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS
3	Sample Loca																								
5	Sample			Pu-238					Pu-239					Pu-240					Sr-90						U-23
6	Number	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value
131																									
132	270° 2000'	0.00																							
133	270° 2500'																								
134	292 500'																								
135	292° 500'																								
136	292° 2000'																								
137	292.5° 500'	0.00																							
138	292.5° 2000'	0.00																							
139	315° 250'																								
140	315 * 500'																								
141	315° 500'																								
142	315° 1000'																								
143	315° 1000'																								
144	315° 1500'																								
145																									
146	315° 2000'	0.00																							
147	315.0° 2500'																								
148	315° 2500'																								
149	337°-337.5° 250																								
150	337° 500'																								
151																									
152	337° 1000'																								
153																									
154																									
155	337° 2000'																								
156	337.5° 1500'																								
157	337.5° 1500'	0.00																							
158	337.5° 2500'	0.00																0.24	0.07	0.10	0.03	0.19			
159	0BLS0101		0.02	0.03			0.0199	0.011	0.0105			0.010	0.011	0.0105			0.0105	-0.1	0.1			-0.10			
160	0BLS0201		0.01	0.02			0.0099	-0	0.0108			-0.001	-0	0.0108			-0.0009	-0.2	0.1			-0.20			
161	0BLS0301		0.0005	0.016			0.0005	0.04	0.03			0.040	0.04	0.03			0.04	-0.4	0.3			-0.39			
162	0BLS0401		0.02	0.03			0.0199	0.06	0.04			0.060	0.06	0.04			0.06	-0.5	0.3			-0.49			
163	0BLS0501		0.0004	0.0104			0.0004	0.04	0.03			0.040	0.04	0.03			0.04	-0.2	0.1			-0.20			
164	0BLS0601		0.05	0.04			0.0497	0.05	0.04			0.050	0.05	0.04			0.05	0.1	0.1			0.10			
165	0BLS0701		0.0004	0.0102			0.0004	0.02	0.03			0.020	0.02	0.03			0.02	-0	0.09			-0.04			
166	0BLS0801		-4E-04	0.0102			-0.0004	0.06	0.03	0.000		0.060	0.06	0.03	0		0.06	-0.1	0.1			-0.10			
167	0BLS0901		0.0005	0.0105			0.0005	0.06	0.03	0.000		0.060	0.06	0.03	0		0.06	-0.1	0.09			-0.06			
168	0BLS1001		0.0005	0.0106			0.0005	0.02	0.03			0.020	0.02	0.03			0.02	-0.2	0.1			-0.20			
169	5ANE0101																								
170	5ANE0201																								
171	5ANE0301																								

	A	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR
1																										
2																										
3	Sample Loca																									
4						U-238					Mn-54					Sb-125					Be-7					Eu-15
5	Sample					U-238					Mn-54					Sb-125					Be-7					Eu-15
6	Number	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma
7		Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Valu	(+/-)	Value	Value	Activity	Value	(+/-)	Value
131																										
132	270° 2000'																									
133	270° 2500'																									
134	292 500'																									
135	292° 500'																									
136	292° 2000'																									
137	292.5° 500'																									
138	292.5° 2000'																									
139	315° 250'																									
140	315° 500'													0.17	0.06	0.05		0.00								
141	315° 500'																									
142	315° 1000'																									
143	315° 1000'																									
144	315° 1500'																									
145																										
146	315° 2000'																									
147	315.0° 2500'																									
148	315° 2500'																									
149	337°-337.5° 250																									
150	337° 500'																									
151																										
152	337° 1000'																									
153																										
154																										
155	337° 2000'																									
156	337.5° 1500'																									
157	337.5° 1500'																									
158	337.5° 2500'																									
159	0BLS0101			1.3	0.1	1.10	1.00	1.30																		
160	0BLS0201			1.05	0.09	0.87	0.78	1.05																		
161	0BLS0301			0.91	0.009	0.89	0.88	0.91																		
162	0BLS0401			1.01	0.09	0.83	0.74	1.01																		
163	0BLS0501			0.8	0.007	0.79	0.78	0.80																		
164	0BLS0601			0.8	0.007	0.79	0.78	0.80																		
165	0BLS0701			0.9	0.008	0.89	0.88	0.90																		
166	0BLS0801			0.81	0.008	0.79	0.78	0.80																		
167	0BLS0901			0.8	0.008	0.79	0.78	0.80																		
168	0BLS1001			0.81	0.009	0.79	0.78	0.81																		
169	5ANE0101																									
170	5ANE0201																									
171	5ANE0301																									

	A	CS	CT	CU	CV	CW	CX	CY	CZ	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP
1																									
2																									
3	Sample Loca																								
4																									
5	Sample					Eu-155					Pa-234m					Ru-106					Sc-46				
6	Number	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Valu	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)	2*Sigma Value	3*Sigma Value	Current Activity	Data Value	Error (+/-)
7																									
131																									
132	270° 2000'																								
133	270° 2500'																								
134	292 500'																								
135	292° 500'																								
136	292° 2000'																								
137	292.5° 500'																								
138	292.5° 2000'																								
139	315° 250'																								
140	315 ° 500'																								
141	315° 500'																								
142	315° 1000'			0.12	0.03	0.06	0.03	0.01																	
143	315° 1000'																								
144	315° 1500'																								
145																									
146	315° 2000'																								
147	315.0° 2500'																								
148	315° 2500'																								
149	337°-337.5° 250																								
150	337° 500'																								
151																									
152	337° 1000'																								
153																									
154																									
155	337° 2000'																								
156	337.5° 1500'																								
157	337.5° 1500'																								
158	337.5° 2500'																								
159	0BLS0101																								
160	0BLS0201																								
161	0BLS0301																								
162	0BLS0401																								
163	0BLS0501																								
164	0BLS0601																								
165	0BLS0701																								
166	0BLS0801																								
167	0BLS0901																								
168	0BLS1001																								
169	5ANE0101																								
170	5ANE0201																								
171	5ANE0301																								

	A	DQ	DR	DS	DT	DU	DV	DW	DX
1									
2									
3	Sample Loca								
4									
5	Sample	U-233					U-234		
6	Number	2*Sigma	3*Sigma	Current	Data	Error	2*Sigma	3*Sigma	Current
7		Value	Value	Activity	Valu	(+/-)	Value	Value	Activity
131									
132	270° 2000'								
133	270° 2500'								
134	292 500'								
135	292° 500'								
136	292° 2000'								
137	292.5° 500'								
138	292.5° 2000'								
139	315° 250'								
140	315.° 500'								
141	315° 500'								
142	315° 1000'								
143	315° 1000'								
144	315° 1500'								
145									
146	315° 2000'								
147	315.0° 2500'								
148	315° 2500'								
149	337°-337.5° 250								
150	337° 500'								
151									
152	337° 1000'								
153									
154									
155	337° 2000'								
156	337.5° 1500'								
157	337.5° 1500'								
158	337.5° 2500'								
159	0BLS0101				1.25	0.1	1.1	1.0	1.2
160	0BLS0201				1	0.09	0.8	0.7	1.0
161	0BLS0301				0.81	0.008	0.8	0.8	0.8
162	0BLS0401				0.8	0.008	0.8	0.8	0.8
163	0BLS0501				0.8	0.008	0.8	0.8	0.8
164	0BLS0601				0.71	0.007	0.7	0.7	0.7
165	0BLS0701				0.8	0.008	0.8	0.8	0.8
166	0BLS0801				0.81	0.007	0.8	0.8	0.8
167	0BLS0901				0.81	0.009	0.8	0.8	0.8
168	0BLS1001				0.9	0.009	0.9	0.9	0.9
169	5ANE0101								
170	5ANE0201								
171	5ANE0301								

Appendix B

Dose Equivalent Rate Data Summary

Sample Location	Sample Number	Correlating Phase I or Phase II Sample Number	Nearest Facility	Latitude Deg:Min:Sec	Longitude Deg:Min:Sec	Northing Feet	Easting Feet	Date	0.1 Scale	1 Scale
									Readings in micro rem per hour (μrem/hr) Scale indicates instrument attenuation	
RESL	0 DEG 2000'		ARA	43 31 24.5900	12 49 24.8860	677375.82	481936.10	6/20/90	7	10
RESL	0 DEG 2500'		ARA	43 31 29.5168	12 49 24.9342	677874.68	481936.5	6/20/90	7	10
RESL	0.0 DEG 1500'		ARA					8/1/95		10
RESL	0.0 DEG 250'		ARA					8/1/95		70
RESL	0.0 DEG 500'		ARA					8/1/95		70
RESL	0.0, DEG 1000'		ARA					8/1/95		12
RESL	112.5 DEG 1000'		ARA					8/1/95		10
RESL	112.5 DEG 2000'		ARA	43 30 57.4747	12 48 59.2091	674615.60	483806.4	6/21/90	6	5
RESL	112.5 DEG 250'		ARA					8/1/95		20
RESL	112.5 DEG 2500'		ARA	43 30 55.6935	12 48 52.9796	674431.69	484264	6/21/90	4	5
RESL	112.5 DEG 500'		ARA					8/1/95		20
RESL	135 DEG 2000'		ARA	43 30 51.2760	12 49 6.7183	673992.33	483248.2	6/21/90	5	5
RESL	135 DEG 2500'		ARA	43 30 47.7424	12 49 2.0320	673631.85	483590.7	6/21/90	4	5
RESL	135.0 DEG 1000'		ARA					8/1/95		10
RESL	135.0 DEG 250'		ARA					8/1/95		15
RESL	135.0 DEG 500'		ARA					8/1/95		10
RESL	157.5 DEG 1000'		ARA					8/1/95		15
RESL	157.5 DEG 1500'		ARA					8/1/95		10
RESL	157.5 DEG 2000'		ARA	43 30 46.6027	12 49 14.7301	673523.8	482654.1	6/21/90	5	5
RESL	157.5 DEG 250'		ARA					8/1/95		15
RESL	157.5 DEG 2500'		ARA	43 30 42.0561	12 49 12.2618	673062.04	482832.4	6/21/90	5	5
RESL	157.5 DEG 500'		ARA					8/1/95		10
RESL	180 DEG 2000'		ARA	43 30 45.1634	12 49 24.2729	673383.61	481949.8	6/21/90	6	5
RESL	180 DEG 2500'		ARA	43 30 40.2605	12 49 24.1310	672887.12	481956.30	6/21/90	5	5
RESL	180.0 DEG 1000'		ARA					8/1/95		10
RESL	180.0 DEG 1500'		ARA					8/1/95		10
RESL	180.0 DEG 250'		ARA					8/1/95		20
RESL	180.0 DEG 500'		ARA					8/1/95		20
RESL	202.5 DEG 1000'		ARA					8/1/95		15
RESL	202.5 DEG 1500'		ARA					8/1/95		10
RESL	202.5 DEG 2000'		ARA					8/1/95		10
RESL	202.5 DEG 2000'		ARA	43 30 46.8471	12 49 34.4249	673560	481203	6/21/90	7	10
RESL	202.5 DEG 250'		ARA					8/1/95		15
RESL	202.5 DEG 2500'		ARA	43 30 42.2527	12 49 36.9092	673096.28	481016.3	6/21/90	6	10
RESL	202.5 DEG 3370'		ARA	43 30 37.5865	12 49 42.2425	672323.21	480617.1	6/22/90	5	5
RESL	202.5 DEG 500'		ARA					8/1/95		20
RESL	22.2 DEG 250'		ARA					8/1/95		22
RESL	22.5 DEG 1000'		ARA					8/1/95		20
RESL	22.5 DEG 1500'		ARA					8/1/95		10
RESL	22.5 DEG 2000'		ARA	43 31 23.0605	12 49 14.3333	677214.84	482712.3	6/20/90	8	10
RESL	22.5 DEG 2500'		ARA	43 31 27.6194	12 49 11.7298	677674.92	482907.8	6/20/90	8	10
RESL	22.5 DEG 500'		ARA					8/1/95		50
RESL	225 DEG 2000'		ARA	43 30 51.3337	12 49 43.6286	674019.65	480528.5	6/21/90	7	10
RESL	225 DEG 2500'		ARA	43 30 47.9145	12 49 48.5338	673676.33	480164.3	6/21/90	5	5
RESL	225.0 DEG 1000'		ARA					8/1/95		15
RESL	225.0 DEG 1500'		ARA					8/1/95		10
RESL	225.0 DEG 250'		ARA					8/1/95		15
RESL	225.0 DEG 500'		ARA					8/1/95		25
RESL	247.5 DEG 1000'		ARA					8/1/95		10
RESL	247.5 DEG 1500'		ARA					8/1/95		10
RESL	247.5 DEG 2000'		ARA	43 30 56.5825	12 49 48.6628	674554.03	480161.8	6/21/90	7	10
RESL	247.5 DEG 250'		ARA					8/1/95		10
RESL	247.5 DEG 2500'		ARA	43 30 54.3634	12 49 54.7200	674332.91	479713.6	6/21/90	5	5
RESL	247.5 DEG 500'		ARA					8/1/95		15
RESL	270 DEG 2500'		ARA	3 31 4.8894	12 49 58.4211	675400.83	479449.5	6/21/90	8	10
RESL	270.0 DEG 1000'		ARA					8/1/95		10
RESL	270.0 DEG 250'		ARA					8/1/95		15
RESL	270.0 DEG 500'		ARA					8/1/95		10
RESL	292.5 DEG 2000'		ARA	43 31 12.4618	12 49 50.0539	676162.59	480072.1	6/21/90	8	10
RESL	292.5 DEG 250'		ARA					8/1/95		20
RESL	292.5 DEG 2500'		ARA	43 31 14.4436	12 49 56.4264	676366.99	479604.2	6/21/90	6	5
RESL	292.5 DEG 500'		ARA					8/1/95		20
RESL	315 DEG 2000'		ARA	43 31 18.3630	12 49 44.3933	676756.75	480493.9	6/20/90	7	10
RESL	315 DEG 2500'		ARA	43 31 21.7258	12 49 49.3484	677100.13	480131.54	6/20/90	7	10
RESL	315.0 DEG 1000'		ARA					8/1/95		15

Sample Location	Sample Number	Correlating Phase I or Phase II Sample Number	Nearest Facility	Latitude Deg:Min:Sec	Longitude Deg:Min:Sec	Northing Feet	Easting Feet	Date	0.1 Scale	1 Scale
									Readings in micro rem per hour (μrem/hr) Scale indicates instrument attenuation	
RESL	315.0 DEG 250'		ARA					8/1/95		20
RESL	315.0 DEG 500'		ARA					8/1/95		15
RESL	33.75 DEG 2000'		ARA					8/1/95		12
RESL	337.5 DEG 1000'		ARA					8/1/95		10
RESL	337.5 DEG 2000'		ARA	43 31 23.3230	12 49 34.9098	677253.38	481196.6	6/20/90	7	10
RESL	337.5 DEG 250'		ARA					8/1/95		70
RESL	337.5 DEG 2500'		ARA	43 31 27.8669	12 49 37.4187	677714.91	481015.4	6/20/90	6	10
RESL	337.5 DEG 500'		ARA					8/1/95		40
RESL	45 DEG 2500'		ARA	43 31 23.5708	12 48 59.2944	677257.82	483820.7	6/20/90	7	5
RESL	45.0 DEG 1000'		ARA					8/1/95		20
RESL	45.0 DEG 1500'		ARA					8/1/95		10
RESL	45.0 DEG 2000'		ARA					8/1/95		12
RESL	45.0 DEG 250'		ARA					8/1/95		80
RESL	45.0 DEG 500'		ARA					8/1/95		40
RESL	56.25 DEG 2000'		ARA					8/1/95		20
RESL	67.5 DEG 1000'		ARA					8/1/95		30
RESL	67.5 DEG 1500'		ARA					8/1/95		20
RESL	67.5 DEG 2000'		ARA					8/1/95		15
RESL	67.5 DEG 250'		ARA					8/1/95		80
RESL	67.5 DEG 2500'		ARA					8/1/95		20
RESL	67.5 DEG 500'		ARA					8/1/95		40
RESL	90 DEG 2000'		ARA	3 31 4.9248	12 48 57.4958	675368.93	483938.51	6/22/90	7	10
RESL	90 DEG 2500'		ARA	3 31 4.9646	12 48 50.6982	675369.06	484439.4	6/22/90	7	10
RESL	90.0 DEG 1000'		ARA					8/1/95		10
RESL	90.0 DEG 1500'		ARA					8/1/95		5
RESL	90.0 DEG 250'		ARA					8/1/95		30
RESL	90.0 DEG 500'		ARA					8/1/95		20
PHASE I	BIASED SAMPLE 1 +100'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 1 +150'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 1 +200'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 1 +250'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 1 +300'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 1 +50'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 1 -O'	5ABS01	ARA III			680854.55	324412	4/6/90		10
PHASE I	BIASED SAMPLE 2 +100'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +150'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +200'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +250'		ARA III					4/7/90		15
PHASE I	BIASED SAMPLE 2 +300'		ARA III					4/7/90		15
PHASE I	BIASED SAMPLE 2 +350'		ARA III					4/7/90		15
PHASE I	BIASED SAMPLE 2 +400'		ARA III					4/7/90		20
PHASE I	BIASED SAMPLE 2 +450'		ARA III					4/7/90		15
PHASE I	BIASED SAMPLE 2 +50'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +500'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +550'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +600'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +650'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +700'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +750'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +800'		ARA III					4/7/90		5
PHASE I	BIASED SAMPLE 2 +850'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +900'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 +950'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 2 -0'	5ABS02	ARA III			680554.45	324611.2	4/6/90		10
PHASE I	BIASED SAMPLE 3 +100'		ARA III					4/7/90		5
PHASE I	BIASED SAMPLE 3 +150'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +200'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +250'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +300'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +350'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +400'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +450'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +50'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +500'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +550'		ARA III					4/7/90		10

Sample Location	Sample Number	Correlating Phase I or Phase II Sample Number	Nearest Facility	Latitude Deg:Min:Sec	Longitude Deg:Min:Sec	Northing Feet	Easting Feet	Date	Readings in micro rem per hour (µrem/hr) Scale indicates instrument attenuation	
									0.1 Scale	1 Scale
PHASE I	BIASED SAMPLE 3 +600'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +650'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +700'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +750'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +800'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 +850'		ARA III					4/7/90		10
PHASE I	BIASED SAMPLE 3 -0'	5ABS03	ARA III			680209.31	323805.8	4/6/90		10
PHASE I	NE 1 +100'		ARA I					4/6/90		15
PHASE I	NE 1 +150'		ARA I					4/6/90		15
PHASE I	NE 1 +200'		ARA I					4/6/90		15
PHASE I	NE 1 +250'		ARA I					4/6/90		15
PHASE I	NE 1 +300'		ARA I					4/6/90		15
PHASE I	NE 1 +350'		ARA I					4/6/90		15
PHASE I	NE 1 +400'		ARA I					4/6/90		10
PHASE I	NE 1 +450'		ARA I					4/6/90		10
PHASE I	NE 1 +50'		ARA I					4/6/90		15
PHASE I	NE 1 +500'		ARA I					4/6/90		10
PHASE I	NE 1 +550'		ARA I					4/6/90		10
PHASE I	NE 1 -0'	5ANE01	ARA I			676985.59	328109.5	4/6/90		15
PHASE I	NE 2 +100'		ARA I					4/6/90		10
PHASE I	NE 2 +150'		ARA I					4/6/90		10
PHASE I	NE 2 +200'		ARA I					4/6/90		10
PHASE I	NE 2 +250'		ARA I					4/6/90		10
PHASE I	NE 2 +300'		ARA I					4/6/90		10
PHASE I	NE 2 +350'		ARA I					4/6/90		10
PHASE I	NE 2 +400'		ARA I					4/6/90		10
PHASE I	NE 2 +450'		ARA I					4/6/90		10
PHASE I	NE 2 +50'		ARA I					4/6/90		10
PHASE I	NE 2 +500'		ARA I					4/6/90		10
PHASE I	NE 2 +550'		ARA I					4/6/90		10
PHASE I	NE 2 +600'		ARA I					4/6/90		10
PHASE I	NE 2 +650'		ARA I					4/6/90		10
PHASE I	NE 2 +700'		ARA I					4/6/90		10
PHASE I	NE 2 +750'		ARA I					4/6/90		10
PHASE I	NE 2 -0'	5ANE02	ARA I			677422.55	328546.1	4/6/90		10
PHASE I	NE 3 +10'		ARA I					4/6/90		10
PHASE I	NE 3 +20'		ARA I					4/6/90		10
PHASE I	NE 3 +30'		ARA I					4/6/90		10
PHASE I	NE 3 +40'		ARA I					4/6/90		10
PHASE I	NE 3 +50'		ARA I					4/6/90		10
PHASE I	NE 3 +60'		ARA I					4/6/90		10
PHASE I	NE 3 +70'		ARA I					4/6/90		10
PHASE I	NE 3 +80'		ARA I					4/6/90		10
PHASE I	NE 3 +90'		ARA I					4/6/90		10
PHASE I	NE 3 -0'	5ANE03	ARA I			677967.90	329092.6	4/6/90		10

Appendix C

Toxicity Profiles for the COPCs

This Appendix presents the toxicological profiles for the COPCs at the ARA Windblown sites. Toxicity values (e.g., slope factors and reference doses) are presented in the main body of the document.

Radionuclides

Chronic radiation effects (from all radionuclides) are similar to those produced by ionizing radiation, and carcinogenicity from radiation is related to dose and exposure time.

Cesium-137/Barium (Ba-137m)

Irrespective of the mode of administration, Cs-137 is rapidly absorbed into the bloodstream and distributes throughout the active tissues of the body. Metabolically, Cs-137 behaves as an analog of potassium and Cs-134 should behave similar to Cs-137. Its distribution throughout the body and the energetic beta and gamma radiation from its decay daughter, Ba-137m, result in essentially whole-body irradiation (Amdur et al. 1991).

Cobalt

Treatment with Co-60 is used to kill cancer cells, but cobalt radiation can also affect normal cells and tissues in the body causing cancer. These radiation effects can include serious damage to the lungs, heart, intestines, blood cells, bone, and skin (Hall 1978).

Gamma rays (e.g., europium)

Target organs for gamma ray-induced cancers in humans can include the thyroid, breast, lung, blood (bone marrow), stomach, liver, small and large intestine, brain, bone, esophagus, bladder, pancreas, lymphatic tissues, skin, pharynx, uterus, ovary, and kidney. Breast cancer typically occurs ten years after exposure (BEIR IV 1988), and thyroid cancer is a late consequence of ionizing radiation.

Plutonium

After inhalation, plutonium may remain in the lungs but can move to the bones and liver (BEIR V 1990). It generally stays in the body for a very long time and continues to expose the surrounding tissues to radiation (ATSDR, 1990a). This will eventually increase the chance of developing cancer, but it will be a number of years before such cancer effects become apparent. Plutonium absorption from the gastrointestinal tract appears to be limited but is increased with decreased iron and calcium levels (BEIR IV 1988). Approximately 50% of the plutonium that enters the blood is retained in the bone and 30% in the liver with retention time of 20-50 years (BEIR IV 1988). Inhalation can cause lung tumors in rats and dermal absorption is limited (BEIR IV 1988).

Strontium

Strontium, as a metabolic analog of calcium, is readily absorbed from the gastrointestinal tract or the lungs into the bloodstream and is subsequently deposited in the bones. A single brief intake orally, intravenously, or by inhalation, results in a high incidence of tumors of bones and bone-related tissues (BEIR V 1990).

The major point of yttrium is the lung. Animal studies have shown lung and possible liver damage after exposure to yttrium. (Sittig 1985).

Uranium

Uranium and its compounds are highly toxic. The major target organs for uranium toxicity are the respiratory system, blood, liver, lymphatic, kidneys, skin, and bone marrow (ATSDR 1990b). Cancer of the lung, bone, and lymphatic tissues have been reported for soluble compounds, whereas cancer of the lymphatic and blood-forming tissues has been reported for insoluble compounds (Sittig 1985).

Nonradionuclides

Included with the nonradionuclides is the adverse health effects (i.e., noncarcinogenic) from uranium.

Uranium

After inhalation of insoluble salts of uranium retention in the lungs is prolonged (Amdur et al. 1991), and epidemiological studies have noted increases in death from diseases of the respiratory tract (ATSDR 1990b). Uranium has not been observed to have severe effects on the musculoskeletal system or the liver (ATSDR 1990b). Nonleukemia lymphatic malignancies have occurred from inhalation of uranium compounds, but the latency period is approximately 20 years and that in uranium mill workers, there is a slight excess of cancer deaths from lymphatic tissues and the blood. This may be caused by irradiation of the lymph nodes from TH-230 (ATSDR 1990b). Inhalation of uranium dioxide dust by rats, dogs and monkeys for up to five years showed an increase in concentration in the lymph nodes that accounted for 90% of the body burden, but no evidence of toxicity was observed (Amdur et al. 1991).

Typically, the water soluble forms of uranium are more toxic than the insoluble forms (EPA 1994b). Following ingestion, the uranyl ion is rapidly absorbed from the gastrointestinal tract (Amdur et al. 1991). Approximately 60% of the uranium ingested is excreted in 24 hours and 25% may be fixed to the bone (Amdur et al. 1991). The uranyl ion can cause acute renal damage and failure which may be fatal. However, if exposure is not severe enough, the tissue may be able to regenerate itself (Amdur et al. 1991). There

appears to be a slight decrease in weight after oral ingestion of uranium compounds (EPA 1994b), including fetal body weights (ATSDR 1990b).

A reproductive effect from chronic exposure of rats to uranyl nitrate is degenerative changes in the testes (ATSDR 1990b), and uranium has been shown to cross the placenta and cause fetal damage especially to the skeleton (ATSDR 1990b).

Uranyl nitrate can penetrate the skin in 15 minutes where it accumulates in spaces between different skin layers (ATSDR 1990b). After two days, it is no longer present in the skin, and the animals experience severe toxic signs, including weight loss and death (ATSDR 1990b). After a one day application of uranyl nitrate hexahydrate and uranium tetrachloride, rabbits showed local irritation consisting of coagulation necrosis and decreased permeability, but the skin recovered in less than a week (ATSDR 1990b). Since uranium has a very low gamma radiation component, the effects of dermal or external radiation exposure are expected to be quite minimal (ATSDR 1990b).

The evaluation of noncarcinogenic effects after ingestion of soluble salts of uranium is based on an EPA-established RfD of 3E-03 mg/kg-d (EPA 1994b) that represents critical effects of initial body weight loss and moderate kidney toxicity. An uncertainty factor of 1000 was applied to account for interspecies extrapolation, protection of sensitive individuals, and because a no-observed-adverse-effect-level was obtained from the critical study. There is medium confidence in the critical study, database, and RfD because of the small number of animals used in the study, and there are other studies that discuss the effects of uranium ingestion in other species. Inhalation of soluble salts of uranium is addressed qualitatively.

References

Amdur, M. O., J. Doull, C. D. Klaassen, 1991, "Casarett and Doull's Toxicology, The Basic Science of Poison," 4th ed., Pergamon Press.

ATSDR, 1990a, *Toxicological Profile for Plutonium*, PB91-180406, December.

ATSDR, 1990b, *Toxicological Profile for Uranium*, PB91-180471, December.

EPA, 1994a, *Health Effects Assessment Summary Tables, FY-1994 Annual*, PB94-921199, March.

EPA, 1994b, Integrated Risk Information System (IRIS), On-line Computer Database.

Hall, E. J., 1978, "Radiobiology for the Radiobiologist," 2nd ed., Harper & Row Publishers.

BEIR V, 1990, *Health Effects of Exposures to Low Levels of Ionizing Radiation*, Biological Effects of Ionizing Radiations V, National Academy Press, Washington, D.C.

BEIR IV, 1988, *Health Effects of Radon and Other Internally Deposited Alpha-Emitters*, Biological Effects of Ionizing Radiations IV, National Academy Press, Washington, D.C.

Appendix D

Select RESRAD Input and Output Files

RESRAD Input and Output Files for the Current Occupational Exposure Scenario

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	17000.00 square meters	Co-60	2.300E-02
Thickness:	0.10 meters	Cs-137	1.180E+02
Cover Depth:	0.00 meters	Eu-152	4.000E-01
		Eu-155	4.000E-02
		Pu-238	1.100E-02
		Sr-90	5.610E+00
		U-233	1.010E+00
		U-235	1.100E-01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 100 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	1.000E+02
TDOSE(t):	9.260E-02	9.069E-02	1.780E-02
M(t):	9.260E-04	9.069E-04	1.780E-04

Maximum TDOSE(t): 9.260E-02 mrem/yr   at t = 0.000E+00 years

Total Excess Cancer Risk CNRSI(i.p.t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground risk	Ground fract.	Inhalation risk	Inhalation fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	Soil risk	Soil fract.
Co-60	0.000E+00	0.0000	1.164E-12	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.366E-10	0.0001
Cs-137	0.000E+00	0.0000	1.644E-09	0.0013	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.180E-06	0.9011
Eu-152	0.000E+00	0.0000	2.317E-11	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.126E-10	0.0005
Eu-155	0.000E+00	0.0000	2.816E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.125E-11	0.0000
Pu-238	0.000E+00	0.0000	2.178E-10	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.031E-09	0.0008
Sr-90	0.000E+00	0.0000	2.838E-10	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.818E-08	0.0750
U-233	0.000E+00	0.0000	1.037E-08	0.0079	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.420E-08	0.0108
U-235	0.000E+00	0.0000	1.048E-09	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.616E-09	0.0012
Total	0.000E+00	0.0000	1.359E-08	0.0104	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.296E-06	0.9896

Total Excess Cancer Risk CNRSI(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All pathways risk	All pathways fract.
Co-60	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.377E-10	0.0001
Cs-137	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.182E-06	0.9024
Eu-152	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.357E-10	0.0006
Eu-155	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.153E-11	0.0000
Pu-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.200E+00	0.0000	1.249E-09	0.0010
Sr-90	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.847E-08	0.0752
U-233	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.457E-08	0.0188
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.664E-09	0.0020
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.310E-06	1.0000

***CNRSI(i.p.t) includes contribution from decay daughter radionuclides

Concentration of radionuclides in different media
at t = 0.000E+00 years*

Radio-Nuclide	Contamina-ted Zone pCi/g	Surface Soil pCi/g	Air Par-ticulate pCi/m**3	Well Water pCi/l	Surface Water pCi/l	Nonleafy Vegetable pCi/kg	Leafy Vegetable pCi/kg	Fodder pCi/kg	Meat pCi/kg	Milk pCi/l	Fish pCi/kg	Crustacea pCi/kg
Ae-227	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60	2.30E-02	2.30E-02	1.35E-07	0.00E+00	0.00E+00	2.54E-01	2.56E-01	2.52E-01	5.68E-01	5.06E-02	0.00E+00	0.00E+00
Cs-137	1.18E+02	1.18E+02	6.92E-04	0.00E+00	0.00E+00	5.24E+03	5.24E+03	5.23E+03	1.24E+04	2.77E+03	0.00E+00	0.00E+00
Eu-152	4.00E-01	4.00E-01	2.35E-06	0.00E+00	0.00E+00	2.22E+00	2.22E+00	2.21E+00	6.98E-01	6.43E-03	0.00E+00	0.00E+00
Eu-155	4.00E-02	4.00E-02	2.35E-07	0.00E+00	0.00E+00	2.21E-01	2.22E-01	2.19E-01	6.92E-02	6.40E-04	0.00E+00	0.00E+00
Gd-152	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pa-231	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pb-210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-238	1.10E-02	1.10E-02	6.45E-08	0.00E+00	0.00E+00	2.76E-03	2.78E-03	2.78E-03	5.69E-04	5.65E-06	0.00E+00	0.00E+00
Ra-226	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	5.61E+00	5.61E+00	3.29E-05	0.00E+00	0.00E+00	7.78E+03	7.79E+03	7.77E+03	4.24E+03	8.60E+02	0.00E+00	0.00E+00
Th-229	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-233	1.01E+00	1.01E+00	5.92E-06	0.00E+00	0.00E+00	4.77E+00	4.77E+00	4.77E+00	2.82E-01	4.60E-01	0.00E+00	0.00E+00
U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-235	1.10E-01	1.10E-01	6.45E-07	0.00E+00	0.00E+00	5.20E-01	5.20E-01	5.20E-01	3.07E-02	5.02E-02	0.00E+00	0.00E+00

*For all foodstuff media, concentrations are adjusted for storage time before use.
 Concentrations in the media occurring in pathways that are suppressed are calculated using the current input parameters,
i.e. using parameters appearing in the input screen when the pathways are active.
The Surface soil is the top layer of soil within the user specified mixing zone/depth.

RESRAD Input and Output Files for the 30-Year Residential Exposure Scenario

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	17000.00 square meters	Co-60	2.300E-02
Thickness:	0.10 meters	Cs-137	1.180E+02
Cover Depth:	0.00 meters	Eu-152	4.000E-01
		Eu-155	4.000E-02
		Pu-238	1.100E-02
		Sr-90	5.610E+00
		U-233	1.010E+00
		U-235	1.500E-01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 100 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+01	1.000E+02
TDOSE(t):	3.028E-01	2.964E-01	1.624E-01	5.089E-02
M(t):	3.028E-03	2.964E-03	1.624E-03	5.089E-04

Maximum TDOSE(t): 3.028E-01 mrem/yr   at t = 0.000E+00 years

Total Excess Cancer Risk CNRSI(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio- Nuclide	Ground risk	fract.	Inhalation risk	fract.	Radon risk	fract.	Plant risk	fract.	Meat risk	fract.	Milk risk	fract.	Soil risk	fract.
Co-60	0.000E+00	0.0000	3.787E-14	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.067E-11	0.0000
Cs-137	0.000E+00	0.0000	1.388E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.391E-06	0.8935
Eu-152	0.000E+00	0.0000	7.870E-12	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.809E-10	0.0002
Eu-155	0.000E+00	0.0000	7.154E-15	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.296E-12	0.0000
Pu-238	0.000E+00	0.0000	2.890E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.284E-09	0.0012
Sr-90	0.000E+00	0.0000	2.319E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.925E-07	0.0719
U-233	0.000E+00	0.0000	1.771E-08	0.0066	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.765E-08	0.0215
U-235	0.000E+00	0.0000	2.412E-09	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.919E-09	0.0033
Total	0.000E+00	0.0000	2.203E-08	0.0082	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.654E-06	0.9918

Total Excess Cancer Risk CNRSI(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Dependent Pathways

Radio- Nuclide	Water risk	fract.	Fish risk	fract.	Radon risk	fract.	Plant risk	fract.	Meat risk	fract.	Milk risk	fract.	All pathways risk	fract.
Co-60	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.070E-11	0.0000
Cs-137	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.392E-06	0.8940
Eu-152	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.888E-10	0.0002
Eu-155	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.303E-12	0.0000
Pu-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.573E-09	0.0013
Sr-90	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.927E-07	0.0720
U-233	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.535E-08	0.0282
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.133E-08	0.0042
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.676E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Concentration of radionuclides in different media
at t = 3.000E+01 years*

Radio-Nuclide	Contaminated Zone pCi/g	Surface Soil pCi/g	Air Particulate pCi/m**3	Well Water pCi/l	Surface Water pCi/l	Nonleafy Vegetable pCi/kg	Leafy Vegetable pCi/kg	Fodder pCi/kg	Meat pCi/kg	Milk pCi/l	Fish pCi/kg	Crustacea pCi/kg
Ac-227	3.39E-05	3.39E-05	1.99E-10	0.00E+00	0.00E+00	4.76E-05	4.71E-05	4.90E-05	1.13E-06	3.93E-07	0.00E+00	0.00E+00
Co-60	4.45E-04	4.45E-04	2.61E-09	0.00E+00	0.00E+00	4.92E-03	4.94E-03	4.87E-03	1.10E-02	9.80E-04	0.00E+00	0.00E+00
Cs-137	5.92E+01	5.92E+01	3.47E-04	0.00E+00	0.00E+00	2.63E+03	2.63E+03	2.63E+03	6.24E+03	1.39E+03	0.00E+00	0.00E+00
Eu-152	8.08E-02	8.08E-02	4.74E-07	0.00E+00	0.00E+00	4.48E-01	4.49E-01	4.46E-01	1.41E-01	1.30E-03	0.00E+00	0.00E+00
Eu-155	6.04E-04	6.04E-04	3.54E-09	0.00E+00	0.00E+00	3.34E-03	3.36E-03	3.30E-03	1.05E-03	9.67E-06	0.00E+00	0.00E+00
Gd-152	1.07E-14	1.07E-14	6.29E-20	0.00E+00	0.00E+00	1.49E-14	1.49E-14	1.50E-14	1.28E-14	1.24E-16	0.00E+00	0.00E+00
Pa-231	9.51E-05	9.51E-05	5.58E-10	0.00E+00	0.00E+00	5.29E-04	5.28E-04	5.30E-04	4.18E-04	3.87E-07	0.00E+00	0.00E+00
Pb-210	1.02E-13	1.02E-13	5.96E-19	0.00E+00	0.00E+00	5.77E-13	5.65E-13	6.06E-13	7.52E-14	2.53E-14	0.00E+00	0.00E+00
Pu-238	8.68E-03	8.68E-03	5.09E-08	0.00E+00	0.00E+00	2.17E-03	2.18E-03	2.18E-03	4.49E-04	4.46E-06	0.00E+00	0.00E+00
Ra-226	5.14E-13	5.14E-13	3.01E-18	0.00E+00	0.00E+00	1.14E-11	1.14E-11	1.14E-11	1.03E-12	8.85E-13	0.00E+00	0.00E+00
Sr-90	2.73E+00	2.73E+00	1.60E-05	0.00E+00	0.00E+00	3.78E+03	3.78E+03	3.77E+03	2.06E+03	4.18E+02	0.00E+00	0.00E+00
Th-229	2.87E-03	2.87E-03	1.68E-08	0.00E+00	0.00E+00	1.37E-03	1.36E-03	1.42E-03	1.55E-04	7.69E-06	0.00E+00	0.00E+00
Th-230	1.17E-10	1.17E-10	6.84E-16	0.00E+00	0.00E+00	5.65E-11	5.54E-11	5.96E-11	6.35E-12	3.17E-13	0.00E+00	0.00E+00
U-233	1.01E+00	1.01E+00	5.92E-06	0.00E+00	0.00E+00	4.77E+00	4.77E+00	4.77E+00	2.82E-01	4.60E-01	0.00E+00	0.00E+00
U-234	8.31E-07	8.31E-07	4.88E-12	0.00E+00	0.00E+00	3.93E-06	3.93E-06	3.93E-06	2.32E-07	3.79E-07	0.00E+00	0.00E+00
U-235	1.50E-01	1.50E-01	8.80E-07	0.00E+00	0.00E+00	7.08E-01	7.09E-01	7.09E-01	4.19E-02	6.84E-02	0.00E+00	0.00E+00

*For all foodstuff media, concentrations are adjusted for storage time before use.
 Concentrations in the media occurring in pathways that are suppressed are calculated using the current input parameters,
i.e. using parameters appearing in the input screen when the pathways are active.
The Surface soil is the top layer of soil within the user specified mixing zone/depth.

RESRAD Input and Output Files for the 100-Year Occupational Exposure Scenario

Contaminated Zone Dimensions	Initial Soil Concentrations, pCi/g	
Area: 17000.00 square meters	Co-60	2.300E-02
Thickness: 0.10 meters	Cs-137	1.180E+02
Cover Depth: 0.00 meters	Eu-152	4.000E-01
	Eu-155	4.000E-02
	Pu-238	1.100E-02
	Sr-90	5.610E+00
	U-233	1.010E+00
	U-235	1.100E-01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 100 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	1.000E+02
TDOSE(t):	9.260E-02	9.069E-02	1.780E-02
M(t):	9.260E-04	9.069E-04	1.780E-04

Maximum TDOSE(t): 9.260E-02 mrem/yr   at t = 0.000E+00 years

Total Excess Cancer Risk CNRSI(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground risk	Ground fract.	Inhalation risk	Inhalation fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	Soil risk	Soil fract.
Co-60	0.000E+00	0.0000	2.263E-18	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.657E-16	0.0000
Cs-137	0.000E+00	0.0000	1.652E-10	0.0011	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.186E-07	0.7589
Eu-152	0.000E+00	0.0000	1.120E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.445E-12	0.0000
Eu-155	0.000E+00	0.0000	2.401E-19	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.812E-17	0.0000
Pu-238	0.000E+00	0.0000	9.885E-11	0.0006	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.681E-10	0.0030
Sr-90	0.000E+00	0.0000	2.557E-11	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.847E-09	0.0566
U-233	0.000E+00	0.0000	1.090E-08	0.0698	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.446E-08	0.0925
U-235	0.000E+00	0.0000	1.065E-09	0.0068	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.640E-09	0.0105
Total	0.000E+00	0.0000	1.226E-08	0.0784	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.440E-07	0.9216

Total Excess Cancer Risk CNRSI(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All pathways risk	All pathways fract.
Co-60	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.679E-16	0.0000
Cs-137	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.188E-07	0.7600
Eu-152	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.557E-12	0.0000
Eu-155	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.836E-17	0.0000
Pu-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.670E-10	0.0036
Sr-90	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.873E-09	0.0568
U-233	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.537E-08	0.1623
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.705E-09	0.0173
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.563E-07	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Concentration of radionuclides in different media
at t = 1.000E+02 years*

Radio-Nuclide	Contamina-ted Zone pCi/g	Surface Soil pCi/g	Air Par-ticulate pCi/m**3	Well Water pCi/l	Surface Water pCi/l	Nonleafy Vegetable pCi/kg	Leafy Vegetable pCi/kg	Fodder pCi/kg	Meat pCi/kg	Milk pCi/l	Fish pCi/kg	Crustacea pCi/kg
Ac-227	1.62E-04	1.62E-04	9.53E-10	0.00E+00	0.00E+00	2.27E-04	2.26E-04	2.30E-04	3.71E-06	1.88E-06	0.00E+00	0.00E+00
Co-60	4.47E-08	4.47E-08	2.62E-13	0.00E+00	0.00E+00	4.95E-07	4.97E-07	4.89E-07	1.10E-06	9.85E-08	0.00E+00	0.00E+00
Cs-137	1.19E+01	1.19E+01	6.96E-05	0.00E+00	0.00E+00	5.27E+02	5.27E+02	5.26E+02	1.25E+03	2.79E+02	0.00E+00	0.00E+00
Eu-152	1.93E-03	1.93E-03	1.13E-08	0.00E+00	0.00E+00	1.07E-02	1.07E-02	1.07E-02	3.38E-03	3.11E-05	0.00E+00	0.00E+00
Eu-155	3.41E-08	3.41E-08	2.00E-13	0.00E+00	0.00E+00	1.89E-07	1.90E-07	1.86E-07	5.90E-08	5.46E-10	0.00E+00	0.00E+00
Gd-152	1.34E-14	1.34E-14	7.85E-20	0.00E+00	0.00E+00	1.86E-14	1.86E-14	1.86E-14	1.59E-14	1.54E-16	0.00E+00	0.00E+00
Pa-231	2.32E-04	2.32E-04	1.36E-09	0.00E+00	0.00E+00	1.29E-03	1.29E-03	1.29E-03	1.02E-03	9.39E-07	0.00E+00	0.00E+00
Pb-210	7.92E-12	7.92E-12	4.65E-17	0.00E+00	0.00E+00	4.44E-11	4.41E-11	4.53E-11	5.68E-12	1.94E-12	0.00E+00	0.00E+00
Pu-238	4.99E-03	4.99E-03	2.93E-08	0.00E+00	0.00E+00	1.25E-03	1.26E-03	1.26E-03	2.58E-04	2.57E-06	0.00E+00	0.00E+00
Ra-226	1.66E-11	1.66E-11	9.73E-17	0.00E+00	0.00E+00	3.69E-10	3.69E-10	3.69E-10	3.34E-11	2.86E-11	0.00E+00	0.00E+00
Sr-90	5.05E-01	5.05E-01	2.96E-06	0.00E+00	0.00E+00	7.01E+02	7.02E+02	7.00E+02	3.82E+02	7.75E+01	0.00E+00	0.00E+00
Th-229	9.54E-03	9.54E-03	5.60E-08	0.00E+00	0.00E+00	4.53E-03	4.53E-03	4.59E-03	5.10E-04	2.52E-05	0.00E+00	0.00E+00
Th-230	1.09E-09	1.09E-09	6.42E-15	0.00E+00	0.00E+00	5.21E-10	5.20E-10	5.31E-10	5.86E-11	2.91E-12	0.00E+00	0.00E+00
U-233	1.01E+00	1.01E+00	5.92E-06	0.00E+00	0.00E+00	4.77E+00	4.77E+00	4.77E+00	2.82E-01	4.60E-01	0.00E+00	0.00E+00
U-234	2.15E-06	2.15E-06	1.26E-11	0.00E+00	0.00E+00	1.02E-05	1.02E-05	1.02E-05	6.01E-07	9.81E-07	0.00E+00	0.00E+00
U-235	1.10E-01	1.10E-01	6.45E-07	0.00E+00	0.00E+00	5.20E-01	5.20E-01	5.20E-01	3.07E-02	5.02E-02	0.00E+00	0.00E+00

*For all foodstuff media. concentrations are adjusted for storage time before use.
 Concentrations in the media occurring in pathways that are suppressed are calculated using the current input parameters,
i.e. using parameters appearing in the input screen when the pathways are active.
The Surface soil is the top layer of soil within the user specified mixing zone/depth.

C:\RES519\RESMAIN3.EXEexecution time =   24.88 seconds

RESRAD Input and Output Files for the 100-Year Residential Exposure Scenario

Contaminated Zone Dimensions			Initial Soil Concentrations, pCi/g	
Area:	17000.00	square meters	Co-60	2.300E-02
Thickness:	0.10	meters	Cs-137	1.180E+02
Cover Depth:	0.00	meters	Eu-152	4.000E-01
			Eu-155	4.000E-02
			Pu-238	1.100E-02
			Sr-90	5.610E+00
			U-233	1.010E+00
			U-235	1.500E-01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 100 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+01	1.000E+02
TDOSE(t):	3.028E-01	2.964E-01	1.624E-01	5.089E-02
M(t):	3.028E-03	2.964E-03	1.624E-03	5.089E-04

Maximum TDOSE(t): 3.028E-01 mrem/yr   at t = 0.000E+00 years

Concentration of radionuclides in different media
at t = 1.000E+02 years*

Radio-Nuclide	Contamina-ted Zone pCi/g	Surface Soil pCi/g	Air Par-ticulate pCi/m**3	Well Water pCi/l	Surface Water pCi/l	Nonleafy Vegetable pCi/kg	Leafy Vegetable pCi/kg	Fodder pCi/kg	Meat pCi/kg	Milk pCi/l	Fish pCi/kg	Crustacea pCi/kg
Ac-227	2.22E-04	2.22E-04	1.30E-09	0.00E+00	0.00E+00	3.09E-04	3.08E-04	3.14E-04	5.06E-06	2.56E-06	0.00E+00	0.00E+00
Co-60	4.47E-08	4.47E-08	2.62E-13	0.00E+00	0.00E+00	4.95E-07	4.97E-07	4.89E-07	1.10E-06	9.85E-08	0.00E+00	0.00E+00
Cs-137	1.19E+01	1.19E+01	6.96E-05	0.00E+00	0.00E+00	5.27E+02	5.27E+02	5.26E+02	1.25E+03	2.79E+02	0.00E+00	0.00E+00
Eu-152	1.93E-03	1.93E-03	1.13E-08	0.00E+00	0.00E+00	1.07E-02	1.07E-02	1.07E-02	3.38E-03	3.11E-05	0.00E+00	0.00E+00
Eu-155	3.41E-08	3.41E-08	2.00E-13	0.00E+00	0.00E+00	1.89E-07	1.89E-07	1.86E-07	5.90E-08	5.46E-10	0.00E+00	0.00E+00
Gd-152	1.34E-14	1.34E-14	7.85E-20	0.00E+00	0.00E+00	1.86E-14	1.86E-14	1.86E-14	1.59E-14	1.54E-16	0.00E+00	0.00E+00
Pa-231	3.17E-04	3.17E-04	1.86E-09	0.00E+00	0.00E+00	1.76E-03	1.76E-03	1.76E-03	1.39E-03	1.28E-06	0.00E+00	0.00E+00
Pb-210	7.92E-12	7.92E-12	4.65E-17	0.00E+00	0.00E+00	4.44E-11	4.41E-11	4.53E-11	5.68E-12	1.94E-12	0.00E+00	0.00E+00
Pu-238	4.99E-03	4.99E-03	2.93E-08	0.00E+00	0.00E+00	1.25E-03	1.26E-03	1.26E-03	2.58E-04	2.57E-06	0.00E+00	0.00E+00
Ra-226	1.66E-11	1.66E-11	9.73E-17	0.00E+00	0.00E+00	3.69E-10	3.69E-10	3.69E-10	3.34E-11	2.86E-11	0.00E+00	0.00E+00
Sr-90	5.05E-01	5.05E-01	2.96E-06	0.00E+00	0.00E+00	7.01E+02	7.02E+02	7.00E+02	3.82E+02	7.75E+01	0.00E+00	0.00E+00
Th-229	9.54E-03	9.54E-03	5.60E-08	0.00E+00	0.00E+00	4.53E-03	4.52E-03	4.58E-03	5.10E-04	2.52E-05	0.00E+00	0.00E+00
Th-230	1.09E-09	1.09E-09	6.42E-15	0.00E+00	0.00E+00	5.21E-10	5.19E-10	5.30E-10	5.86E-11	2.91E-12	0.00E+00	0.00E+00
U-233	1.01E+00	1.01E+00	5.92E-06	0.00E+00	0.00E+00	4.77E+00	4.77E+00	4.77E+00	2.82E-01	4.60E-01	0.00E+00	0.00E+00
U-234	2.15E-06	2.15E-06	1.26E-11	0.00E+00	0.00E+00	1.02E-05	1.02E-05	1.02E-05	6.01E-07	9.81E-07	0.00E+00	0.00E+00
U-235	1.50E-01	1.50E-01	8.80E-07	0.00E+00	0.00E+00	7.08E-01	7.09E-01	7.09E-01	4.19E-02	6.84E-02	0.00E+00	0.00E+00

*For all foodstuff media, concentrations are adjusted for storage time before use.
 Concentrations in the media occurring in pathways that are suppressed are calculated using the current input parameters,
 i.e. using parameters appearing in the input screen when the pathways are active.
 The Surface soil is the top layer of soil within the user specified mixing zone/depth.

C:\RES519\RESMAIN3.EXEexecution time =   25.93 seconds

Total Excess Cancer Risk CNRSI(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground risk	Ground fract.	Inhalation risk	Inhalation fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	Soil risk	Soil fract.
Co-60	0.000E+00	0.0000	3.806E-18	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.072E-15	0.0000
Cs-137	0.000E+00	0.0000	2.779E-10	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.788E-07	0.7913
Eu-152	0.000E+00	0.0000	1.884E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.391E-11	0.0000
Eu-155	0.000E+00	0.0000	4.038E-19	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.315E-17	0.0000
Pu-238	0.000E+00	0.0000	1.662E-10	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.889E-09	0.0031
Sr-90	0.000E+00	0.0000	4.301E-11	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.571E-08	0.0590
U-233	0.000E+00	0.0000	1.833E-08	0.0303	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.838E-08	0.0965
U-235	0.000E+00	0.0000	2.443E-09	0.0040	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.028E-09	0.0149
Total	0.000E+00	0.0000	2.126E-08	0.0351	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.838E-07	0.9649

Total Excess Cancer Risk CNRSI(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All pathways risk	All pathways fract.
Co-60	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.076E-15	0.0000
Cs-137	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.790E-07	0.7917
Eu-152	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.409E-11	0.0000
Eu-155	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.356E-17	0.0000
Pu-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.056E-09	0.0034
Sr-90	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.575E-08	0.0591
U-233	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.671E-08	0.1268
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.147E-08	0.0190
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.050E-07	1.0000

***CNRSI(i.p.t) includes contribution from decay daughter radionuclides

Appendix E

Food Crop Ingestion Spreadsheets

Site: ARA Windblown Area

CoPC	Oral Toxicity Values				Residential									
	SF (risk/pCi) (mg/kg-d) risk/mg)	RfD	CT (pCi/g, mg/kg	particulate {} in air (g/m3)	CoPC conc. in air (mg/m3)	CoPC conc. in air (pCi/m3)	Fall Speed (m/s)	Deposition Flux (mg/m2-s)	Deposition Flux (pCi/m2-s)	Plant conc (d) (mg/kg)	Plant conc (d) (pCi/kg)	Plant conc (u) (mg/kg, pCi/kg)	Risk	HQ
Cs-137	3.16E-11		1.18E+02	6.00E-06		3.56E-04	4.80E-03		1.71E-06		9.01E+00	4.74E+03	1.83E-05	
Co-60	1.89E-11		2.30E-02	6.00E-06		2.67E-09	4.80E-03		1.28E-11		6.77E-05	8.90E-03	2.06E-11	
Eu-152	5.73E-12		4.00E-01	6.00E-06		5.20E-07	4.80E-03		2.50E-09		1.32E-02	8.67E-01	6.14E-10	
Eu-155	1.65E-12		4.00E-02	6.00E-06		3.63E-09	4.80E-03		1.74E-11		9.20E-05	6.05E-03	1.23E-12	
Pu-238	2.95E-10		1.10E-02	6.00E-06		5.21E-08	4.80E-03		2.50E-10		1.32E-03	3.91E-03	1.88E-10	
Sr-90	5.59E-11		5.61E+00	6.00E-06		1.63E-05	4.80E-03		7.81E-08		4.12E-01	6.78E+03	4.62E-05	
U-233	4.48E-11		1.01E+00	6.00E-06		6.06E-06	4.80E-03		2.91E-08		1.54E-01	8.61E+00	4.78E-08	
U-235	4.70E-11		1.50E-01	6.00E-06		9.00E-07	4.80E-03		4.32E-09		2.28E-02	1.28E+00	7.46E-09	
Uranium		3.00E-03	3.15E+00	6.00E-06	1.89E-08		4.80E-03	9.07E-11		4.79E-04		2.69E-02		1.45E-03
												Total	6.45E-05	1.45E-03

Site: ARA Windblown (100-yr residential)

CoPC	Oral Toxicity Values				Residential								
	SF (risk/pCi) risk/mg)	RfD (mg/kg-d)	CT (pCi/g, mg/kg	particulate [] in air (g/m3)	CoPC conc. in air (mg/m3)	CoPC conc. in air (pCi/m3)	Fall Speed (m/s)	Deposition Flux (mg/m2-s)	Deposition Flux (pCi/m2-s)	Plant conc (d) (mg/kg)	Plant conc (d) (pCi/kg)	Plant conc (u) (mg/kg, pCi/kg)	Risk
Cs-137	3.16E-11		1.18E+02	6.00E-06		7.14E-05	4.80E-03		3.43E-07		1.81E+00	9.51E+02	3.67E-06
Sr-90	5.59E-11		5.61E+00	6.00E-06		2.98E-06	4.80E-03		1.43E-08		7.56E-02	1.24E+03	8.47E-06
												Total	1.21E-05

Appendix F

Nonradiological Hazard Quotient Spreadsheet

SUMMARY OF RISKS FOR NONRADIOACTIVE COPCs

Site: ARA Windblown

Contaminant	Soil Concentration (mg/kg) 0-10 cm	Soil Ingestion Occupational HQ	Residential HQ
Uranium	3.15E+00	5E-04	4E-03

HQ = Hazard quotient

Appendix G

Ecological Based Screening Levels

Table G-1. Ecologically based screening levels (EBSLs) for internal dose from radionuclides (pCi/g) and nonradionuclides (mg/kg) surface soil contamination.

Functional groups	Co-60	Cs-137	Eu-152	Eu-155	Pu-238	Sr-90	U-233	U-235	Uranium
Avian herbivores (AV121)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	1E+05	9E+02	——
Avian herbivores (AV122)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	3E+05	5E+02	——
Avian herbivores (AV132)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	4E+04	5E+02	——
Avian herbivores (AV142)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	1E+04	5E+02	——
Avian herbivores (AV143)	3E+04	7E+04	3E+04	4E+05	4E+03	3E+04	2E+05	6E+03	——
Avian insectivores (AV210)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	1E+05	9E+02	——
Avian insectivores (AV210A)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	1E+05	9E+02	——
Avian insectivores (AV221)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	2E+05	9E+02	——
Avian insectivores (AV222)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	1E+05	5E+02	——
Avian insectivores (AV222A)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	1E+05	9E+02	——
Avian insectivores (AV232)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	8E+04	9E+02	——
Avian insectivores (AV233)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	8E+04	9E+02	——
Avian insectivores (AV241)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	6E+04	9E+02	——
Avian insectivores (AV242)	8E+03	2E+04	8E+03	1E+05	1E+03	8E+03	6E+04	2E+03	——
Avian carnivores (AV310)	5E+04	1E+05	4E+04	7E+05	7E+03	6E+04	5E+05	9E+03	——
Peregrine falcon and northern goshawk	2E+04	6E+04	2E+04	3E+05	4E+03	3E+04	2E+05	5E+03	——
Avian carnivores (AV322)	3E+03	7E+03	3E+03	4E+04	4E+02	4E+03	6E+04	5E+02	——
Bald eagle, ferruginous hawk and loggerhead shrike	1E+03	3E+03	1E+03	2E+04	2E+02	2E+03	3E+04	3E+02	——
Avian carnivores (AV333)	5E+03	1E+04	4E+03	6E+04	7E+02	6E+03	2E+04	9E+02	——
Avian omnivores (AV422)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	1E+04	5E+02	——
Avian omnivores (AV432)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	7E+03	9E+02	——
Avian omnivores (AV433)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	9E+03	9E+02	——
Avian omnivores (AV442)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	7E+02	9E+02	——
Mammalian herbivores (M121)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	2E+05	5E+02	4E+01
Mammalian herbivores (M122)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	1E+05	5E+02	1E+01
Mammalian herbivores (M122A)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	3E+04	5E+02	1E+01
Pygmy rabbit	1E+03	3E+03	1E+03	2E+04	2E+02	1E+03	2E+04	2E+02	7E+00
Mammalian herbivores (M123)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	2E+05	5E+02	2E+01
Mammalian insectivores (M210)	5E+03	1E+04	4E+03	6E+04	7E+02	4E+03	2E+05	9E+02	9E+00
Townsend's western big-eared bat	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	1E+05	5E+02	1E+00
Mammalian insectivores (M210A)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	3E+05	5E+02	5E-01
Mammalian insectivores (M222)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	4E+05	5E+02	5E-01
Mammalian carnivore (M322)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	1E+04	5E+02	9E-01
Mammalian omnivores (M422)	2E+03	6E+03	2E+03	3E+04	4E+02	3E+03	1E+05	5E+02	1E+00
Mammalian omnivores (M422A)	3E+05	7E+05	3E+05	4E+06	5E+04	4E+05	6E+04	6E+04	5E+02
Reptilian insectivores (R222)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	4E+06	5E+02	——
Reptilian carnivores (R322)	2E+03	6E+03	2E+03	3E+04	4E+02	2E+03	2E+05	5E+02	——
plants	1E+06	7E+05	2E+06	3E+07	8E+06	3E+04	5E+05	5E+05	——

— No toxicity data available.

Table G-2. Screening level quotients (SLQs) for internal dose for surface soil exposure.

Concentration Terms	2E-02	1E+02	4E-01	4E-02	1E-02	6E+00	1E+00	2E-01	3E+00
Functional groups	Co-60	Cs-137	Eu-152	Eu-155	Pu-238	Sr-90	U-233	U-235	Uranium
Avian herbivores (AV121)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	9E-06	2E-04	——
Avian herbivores (AV122)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	4E-06	3E-04	——
Avian herbivores (AV132)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	2E-05	3E-04	——
Avian herbivores (AV142)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	8E-05	3E-04	——
Avian herbivores (AV143)	8E-07	2E-03	1E-05	1E-07	2E-06	2E-04	6E-06	3E-05	——
Avian insectivores (AV210)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	7E-06	2E-04	——
Avian insectivores (AV210A)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	9E-06	2E-04	——
Avian insectivores (AV221)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	6E-06	2E-04	——
Avian insectivores (AV222)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	8E-06	3E-04	——
Avian insectivores (AV222A)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	8E-06	2E-04	——
Avian insectivores (AV232)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	1E-05	2E-04	——
Avian insectivores (AV233)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	1E-05	2E-04	——
Avian insectivores (AV241)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	2E-05	2E-04	——
Avian insectivores (AV242)	3E-06	6E-03	5E-05	3E-07	9E-06	7E-04	2E-05	9E-05	——
Avian carnivores (AV310)	5E-07	1E-03	9E-06	6E-08	2E-06	9E-05	2E-06	2E-05	——
Peregrine falcon and northern goshawk	1E-06	2E-03	2E-05	1E-07	3E-06	2E-04	4E-06	3E-05	——
Avian carnivores (AV322)	8E-06	2E-02	2E-04	1E-06	3E-05	2E-03	2E-05	3E-04	——
Bald eagle, ferruginous hawk and loggerhead shrike	2E-05	4E-02	3E-04	2E-06	5E-05	3E-03	3E-05	6E-04	——
Avian carnivores (AV333)	5E-06	1E-02	9E-05	6E-07	2E-05	9E-04	5E-05	2E-04	——
Avian omnivores (AV422)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	7E-05	3E-04	——
Avian omnivores (AV432)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	1E-04	2E-04	——
Avian omnivores (AV433)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	1E-04	2E-04	——
Avian omnivores (AV442)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	1E-03	2E-04	——
Mammalian herbivores (M121)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	6E-06	3E-04	8E-02
Mammalian herbivores (M122)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	9E-06	3E-04	3E-01
Mammalian herbivores (M122A)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	3E-05	3E-04	2E-01
Pygmy rabbit	2E-05	4E-02	4E-04	2E-06	6E-05	5E-03	6E-05	7E-04	5E-01
Mammalian herbivores (M123)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	4E-06	3E-04	2E-01
Mammalian insectivores (M210)	5E-06	1E-02	9E-05	6E-07	2E-05	1E-03	4E-06	2E-04	4E-01
Townsend's western big-eared bat	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	8E-06	3E-04	3E+00
Mammalian insectivores (M210A)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	4E-06	3E-04	6E+00
Mammalian insectivores (M222)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	3E-06	3E-04	7E+00
Mammalian carnivore (M322)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	7E-05	3E-04	3E+00
Mammalian omnivores (M422)	1E-05	2E-02	2E-04	1E-06	3E-05	2E-03	7E-06	3E-04	3E+00
Mammalian omnivores (M422A)	8E-08	2E-04	1E-06	9E-09	2E-07	1E-05	2E-05	3E-06	6E-03
Reptilian insectivores (R222)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	2E-07	3E-04	——
Reptilian carnivores (R322)	1E-05	2E-02	2E-04	1E-06	3E-05	3E-03	5E-06	3E-04	——
plants	2E-08	2E-04	2E-07	1E-09	1E-09	2E-04	2E-06	3E-07	

— No toxicity data available.

Table G-3. Ecologically based screening levels (EBSLs) for external dose from radionuclides (pCi/g) surface soil contamination.

Functional Groups	Co-60	Cs-137	Eu-152	Eu-155	Pu-238	Sr-90	U-233	U-235
Avian herbivores (AV121)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian herbivores (AV122)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian herbivores (AV132)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian herbivores (AV142)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian herbivores (AV143)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian insectivores (AV210)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian insectivores (AV210A)	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Avian insectivores (AV221)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian insectivores (AV222)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian insectivores (AV222A)	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Avian insectivores (AV232)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian insectivores (AV233)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian insectivores (AV241)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian insectivores (AV242)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian carnivores (AV310)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Peregrine falcon and northern goshawk	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Avian carnivores (AV322)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Bald eagle, ferruginous hawk and loggerhead shrike	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Avian carnivores (AV333)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian omnivores (AV422)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian omnivores (AV432)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian omnivores (AV433)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Avian omnivores (AV442)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Mammalian herbivores (M121)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Mammalian herbivores (M122)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Mammalian herbivores (M122A)	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Pygmy rabbit	4E+02	2E+03	8E+02	2E+04	4E+07	No dose	7E+06	3E+07
Mammalian herbivores (M123)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Mammalian insectivores (M210)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Townsend's western big-eared bat	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Mammalian insectivores (M210A)	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Mammalian insectivores (M222)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Mammalian carnivore (M322)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Mammalian omnivores (M422)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Mammalian omnivores (M422A)	8E+02	3E+03	2E+03	4E+04	7E+07	No dose	1E+07	6E+07
Reptilian insectivores (R222)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
Reptilian carnivores (R322)	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08
plants	2E+03	7E+03	3E+03	8E+04	1E+08	No dose	3E+07	1E+08

Table G-4. Screening level quotients (SLQs) for external dose for surface soil exposure.

Concentration Terms	2E-02	1E+02	4E-01	4E-02	1E-02	6E+00	1E+00	2E-01
Functional Group	Co-60	Cs-137	Eu-152	Eu-155	Pu-238	Sr-90	U-233	U-235
Avian herbivores (AV121)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian herbivores (AV122)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian herbivores (AV132)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian herbivores (AV142)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian herbivores (AV143)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian insectivores (AV210)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian insectivores (AV210A)	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Avian insectivores (AV221)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian insectivores (AV222)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian insectivores (AV222A)	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Avian insectivores (AV232)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian insectivores (AV233)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian insectivores (AV241)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian insectivores (AV242)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian carnivores (AV310)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Peregrine falcon and northern goshawk	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Avian carnivores (AV322)	·1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Bald eagle, ferruginous hawk and loggerhead shrike	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Avian carnivores (AV333)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian omnivores (AV422)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian omnivores (AV432)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian omnivores (AV433)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Avian omnivores (AV442)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Mammalian herbivores (M121)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Mammalian herbivores (M122)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Mammalian herbivores (M122A)	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Pygmy rabbit	6E-05	7E-02	5E-04	2E-06	3E-10	No dose	2E-07	5E-09
Mammalian herbivores (M123)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Mammalian insectivores (M210)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Townsend's western big-eared bat	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Mammalian insectivores (M210A)	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Mammalian insectivores (M222)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Mammalian carnivore (M322)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Mammalian omnivores (M422)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Mammalian omnivores (M422A)	3E-05	4E-02	3E-04	1E-06	2E-10	No dose	8E-08	3E-09
Reptilian insectivores (R222)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
Reptilian carnivores (R322)	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09
plants	1E-05	2E-02	1E-04	5E-07	8E-11	No dose	4E-08	1E-09

FFA/CO PROJECT MANAGER MEETING MINUTES
February 28, 1995

Teleconference

PARTICIPANTS:

Lisa Green, Donna Nicklaus - DOE-ID
Wayne Pierre - EPA
Dean Nygard, Shawn Rosenberger - IDHW
Greg Bass, - DOE-AAO
Dary Newbry - DOE-IBO, NRF
Tom Stoops, Susie Burns, Doug Greenwell, Dan Haley, - LITCO

HIGHLIGHTS:

1) Meeting minutes for February 15 and 22 were approved by DOE, EPA, and IDHW.

2) OU 4-09 Track 2 Investigation: The RPMs have previously designated the following Track 1 sites to proceed to Track 2 investigations:
   OU 4-03, CFA 45, former location of UST CFA -605W,
   OU 4-07, CFA-07, French drains at buildings CFA-633, and
   OU 4-07, CFA-12, French drains at building CFA-690.
   DOE-ID requested that these sites be investigated as a single Track 2 rather than three separate investigations. EPA and IDHW noted that they had, in essence, granted approval through approval of the SOW for OU 4-09, which already included the aforementioned sites. However, EPA, IDHW, and DOE agreed that the site designations would remain unchanged.

3) TAN Value Engineering Session

   DOE recommended Clay Nichols as the moderator/facilitator for the upcoming Value Engineering session; EPA and IDHW agreed.

   An agenda was faxed to IDHW and EPA early this morning. Today's discussion resulted in minor modifications to the agenda; the modified agenda will be sent to the participants today.

   The location of the meeting was changed from University Place to the IDHW offices on Skyline Drive.

4)   OU 10-06 : DOE faxed a list of issues regarding OU 10-06 soils. Concerning one issue, DOE recommended that the OU 10-06 windblown soils around ARA be rolled into the WAG 5 Comprehensive RI/FS; EPA and IDHW agreed with this recommendation.

      Possible alternatives for use of existing containment structures: DOE recommended that OU 10-06 would evaluate the use of an existing containment structure, evaluate OU 10-06 contribution, and final action needed to be addressed by the OU 10-06 Operations and Maintenance (O&M) report with possible handoff to a WAG specific O&M report. EPA and IDHW requested deferment of a decision until the March 15 teleconference, but agreed that the concept of using existing containment structures was reasonable.

5)   Site Prioritization Exercise: DOE-ID sent the letter to DOE-HQ which discusses the proposed site prioritization system. That letter included EPA and IDHW comments.

6)   DOE notified EPA and IDHW that DOE-HQ has issued guidance on working up front with stakeholders on EM budget priorities. DOE will fax the information request to the EPA and IDHW.

AGENDA FOR NEXT CONFERENCE CALL:

●   Due to the VE session next week, the normal weekly teleconference has been canceled. The next teleconference will be Wednesday, March 15, 1995 at 8:30 AM MST.

●   The milestone log will be one topic of discussion.

DECISIONS: No formal decisions were made.

●   See item 4 above.

APPROVAL OF MINUTES: Verbal approval of the minutes accepted by all three agencies on March 15, 1995.